REPORT

GEOTECHNICAL INVESTIGATION

SOUTHWEST PUMP STATION IMPROVEMENTS-PACKAGE II

WBS NO. S-001000-0047-4

HOUSTON, TEXAS

PREPARED BY

ASSOCIATED TESTING LABORATORIES, INC.

HOUSTON, TEXAS

ATL REPORT NO. G13-225

April 25, 2014

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April 25, 2014

ATL Job No: G13-225

KITS Professionals, Inc.
2000 W Sam Houston Parkway S, Suite 1400
Houston, Texas 77042

Attention: Mr. Srikanth Punukula, P.E.

Reference: Final Geotechnical Investigation Report
Southwest Pump Station Improvements – Package II
WBS No. S-001000-0047-4
Houston, Texas

Dear Mr. Punukula:

We have completed the report for the geotechnical investigation for the above-referenced project. Our findings, geotechnical engineering analyses and recommendations are presented in this report.

It has been a pleasure working with you on this project. Should you have any questions concerning this project work, please call us at (713) 748-3717.

Sincerely,

ASSOCIATED TESTING LABORATORIES, INC.

STATE OF TEXAS
PENG SIA TANG
81150
REGISTERED
PROFESSIONAL ENGINEER

4/25/14

Peng Sia Tang, P. E.
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President

GEOTECHNICAL INVESTIGATION

SOUTHWEST PUMP STATION IMPROVEMENTS – PACKAGE II

HOUSTON, TEXAS

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EXECUTIVE SUMMARY

Associated Testing Laboratories, Inc. (ATL) has completed the geotechnical study at the site of the proposed Southwest Pump Station (SWPS) Improvements, as shown in Figure 1. The project entails entails installing approximately 2,000 linear feet (LF) of 30-inch diameter water line from the Southwest Pump Station (SWPS), crossing US 59, and along Richmond Avenue to Mid Lane, using open cut and tunneling technique, in the City of Houston, Texas. The depths of the proposed water lines range from about 14 to about 20 feet below existing grade (see Figure 2).

Both open cut/trenching and tunneling/trenchless installation techniques will be employed. The subsurface conditions investigated by five soil borings (to depth of 24 to 35 feet below existing grade) along the project alignments, consists The subsurface soils along the project alignments consist of an upper stratum of stiff to hard Fat Clays (CH) and Lean Clays (CL) that exists to the bottom of the 24-ft deep Boring B-3, and to depths of about 28, 33, 28 and 27 feet in Boring B-1, B-2, B-4 and B-5, respectively. This upper clay stratum is underlain by a stratum of loose to very dense Silty Sands (SM) that exists to the bottom of Boring B-1, B-2, B-4 and B-5 at a depth of 35, 35, 34 and 29 feet below existing grade, respectively. Detailed subsurface soils and stratigraphy are shown in the individual boring logs in Appendix 3 and in the Boring Log Profile in Figure 4.

Free water was encountered during drilling operation in Boring B-1, B-2, B-4 and B-5 at a depth of about 17, 33, 28 and 27 feet, respectively; free water was measured in Borings B-2 and B-4 after 5 minutes at a depth of about 28 and 19 feet, respectively. Boring B-3 was dry during and at completion of drilling operation. Borings B-1 and B-4 were converted into Piezometer PZ-1 and PZ-2 after completion of drilling and soil sampling. Water level in PZ-1 and PZ-2 was measured after

24-hour at a depth of about 14.5 and 17 feet, respectively. Water level in PZ-1 and PZ-2 was measured after 7 days at a depth of about 10.5 and 12.5 feet, respectively; water level in PZ-1 and PZ-2 was measured after 30 days at a depth of about 10 and 11 feet, respectively.

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Our main geotechnical findings and recommendations are summarized below:

1. No unusual staining or hydrocarbon-like odor was noted in the soil samples recovered from the soil borings drilled in ATL's geotechnical investigation.
2. A preliminary fault evaluation based on review of available fault maps and literature review indicated that it does not appear that any known faults are crossing the project alignments.
3. Based on proposed flow line depths and the subsurface conditions (see Figure 4), the water line installation excavations will most likely be advanced in stiff to hard clays.
4. Based on the proposed invert elevation and the gathered groundwater information, the water line construction excavations approaching or exceeds about 10 feet will likely to encounter groundwater. However, it should be noted that groundwater level will fluctuate with the amount of precipitation prior to and during the construction.
5. Geotechnical parameters/information and construction recommendations for the proposed open cut/trenching and trenchless installation of the proposed water lines are presented in Section 5. Construction considerations are provided in Section 6.

GEOTECHNICAL INVESTIGATION
SOUTHWEST PUMP STATION IMPROVEMENTS – PACKAGE II
HOUSTON, TEXAS

1.0 INTRODUCTION

1.1 General

The geotechnical investigation for the proposed Southwest Pump Station Improvements – Package II was authorized by Mr. Srikanth Punukula with the acceptance of the **Associated Testing Laboratories, Inc., (ATL)** Proposal No. CP13-1001 (dated October 9, 2013). Project details were provided to ATL by KITS Professionals, Inc. This report includes results of the field investigation, laboratory testing, geotechnical engineering analysis and recommendations for the proposed pump station improvements for this project.

1.2 Location and Description of the Project

The project sites of this project are located in a mixed commercial and residential neighborhood, a Site Vicinity Map showing the project alignments is presented in Figure 1. Photographs of the project sites were taken at the time of our site visit, and some are presented in Appendix 1.

The project entails installing approximately 2,000 linear feet (LF) of 30-inch diameter water line from the Southwest Pump Station (SWPS), crossing US 59, and along Richmond Avenue to Mid Lane, using open cut and tunneling technique, in the City of Houston, Texas. The project alignments traverse streets in the Key Map 491 Z, and are shown in Figure 2.

The approximate invert depths of the proposed water lines at the proposed boring locations, based on information provided by KITS Professionals, Inc., range from about 14 to 20 feet below grade.

1.3 Scope of Work

A geotechnical investigation was conducted to determine subsurface soil conditions along the proposed project alignments and to develop geotechnical engineering recommendations for the construction of new underground utilities consisting of water lines. **Associated Testing Laboratories, Inc. (ATL)** has completed a subsurface exploration program for this project consisted of the following scope:

- Augering through existing asphaltic concrete (AC) pavements at Boring B-3 using the drill rig auger.
- Drilling and sampling a total of five (5) borings (Borings B-1 through B-5), to depths ranging from 24 to 35 feet below existing grade, for a total of 157 lineal feet of drilling, and converting two borings into piezometers (totaling 69 lineal feet) after completion of drilling and sampling.
- Conducting laboratory tests on selected soil samples recovered from the soil borings.
- Developing boring logs and boring log profiles to present the general subsurface soil and groundwater conditions.
- Conducting a preliminary fault review of the project area based on review of available fault maps and literature.

Based on results from the field investigation, laboratory testing and gathered geological information, ATL performed geotechnical analyses to develop geotechnical recommendations for the proposed water lines replacement construction.

2.0 SUBSURFACE INVESTIGATION PROGRAM

The field investigation for this project consisted of drilling and sampling a total of five (5) soil borings and installing two (2) piezometers along the project alignments. The boring/piezometer locations and depths were approved during the proposal phase. The proposed borings and piezometers were selected based on criteria for borings and piezometers specified in City of Houston Department of Public Works and Engineering Design Manual, Chapter 11 "Geotechnical and Environmental Requirements".

One of the five boring, B-3, is located within existing asphaltic concrete (AC) pavement. The existing AC pavement at this boring location was augered through using the drill rig auger. The information from our boring/piezometer and depths and the coordinates (northing and easting) are presented in the table below.

TABLE A: BORING AND PIEZOMETER INFORMATION

Boring		Piezometer		Location	Northing	Easting
No.	Depth, ft.	No.	Depth, ft.			
B-1	35	PZ-1	35	Within SWPS	13829865.98	3095147.98
B-2	35	--	--	Feeder Road	13830302.18	3095122.52
B-3	24	--	--	In existing pavement within privalte property	13830478.75	3095454.72
B-4	34	PZ-2	34	Turn lane between EB and WB Richmond Ave.	13830965.80	3095367.67
B-5	29	--	--	Grassy median between EB and WB Richmond Ave.	13830956.89	3094929.86

Boring locations drilled in this geotechnical exploration are shown on Figure 2. The boreholes were drilled dry to the bottom of the boring or to a depth where a borehole started caving in, after which rotary wash boring technique was carried out. In cohesive soils, undisturbed soil samples were collected using a conventional 3-inch O.D. Shelby tube in accordance with ASTM D1587.

Cohesionless soils were sampled using split spoon sampler in accordance with ASTM D1586. All soil samples were examined, classified and logged in the field. A representative portion of each sample was packed in containers to prevent moisture loss. All soil samples were properly labeled and subsequently transported to the ATL laboratory.

Boring B-1 and B-4 were converted into piezometer PZ-1 and PZ-2 after the completion of drilling and sampling. The groundwater level information encountered in the boreholes during and at completion of drilling, and the water level in the piezometer after 24 hours, 7 and 30 days are presented in Table 2. The piezometers were pulled and plugged with cement-bentonite grout after the 30-day water level reading. The piezometer installation reports are presented in Appendix 2.

Upon completion of drilling, the borings where no piezometer was to be installed were backfilled using cement-bentonite grout using a tremie. The cored PCC pavements were patched using portland cement concrete, and the augered AC pavements were patched using cold-mixed asphaltic concrete.

All soil samples were classified according to Unified Soil Classification System (ASTM D-2487). The soil and groundwater information found in each boring are shown on the individual boring logs presented in Appendix 3. A Key to Log Terms and Symbols is also presented in Appendix 3.

3.0 LABORATORY TESTING PROGRAM

Samples obtained from the field were again examined and classified in our laboratory by the geotechnical technician under the supervision of an engineer. Laboratory testing was performed on selected soil samples collected during the field investigation. The laboratory testing program included Atterberg Limits (ASTM D-4318), Density, Moisture Content (ASTM D-2216), Unconfined Compressive Strength (ASTM D-2166), Unconsolidated Undrained Triaxial (ASTM D-2850) and Percent Finer Than No. 200 Sieve (ASTM D-1140) tests. The results of laboratory tests are presented in the boring logs in Appendix 3 and summarized in Table 3. Overall numbers and types of tests performed for this study for this project are presented below:

TABLE B: SUMMARY OF LABORATORY SOIL TESTS

TYPE OF TEST	NUMBER OF TEST
Dry Density	20
Moisture Content	63
Atterberg Limits	20
Unconsolidated Undrained Triaxial	4
Sieve Analysis thru #200	21
Unconfined Compression	16

4.0 SUBSURFACE AND SITE CONDITIONS

4.1 Geology of Coastal Plain

The proposed project area is located within the Gulf Coast Structural Province, a huge sedimentary basin containing several thousand feet of sediments. In general, these sediments consist of loose sands, silts and clays which slope gently toward the Gulf of Mexico.

The site is underlain by the Beaumont Formation of Pleistocene age. This formation consists of over consolidated clays, silts and sands with some shell calcium carbonate and iron oxides. These formations are quite strong and extend to an approximate depth of 100 feet. The near surface materials are often weakened by the weathering process.

4.2 Geologic Faults

Among the geologic and geomorphological features in this region are sedimentary deposits broken by structure such as normal faults, salt domes, etc. The sedimentary deposits slope gently toward the Gulf of Mexico. They are broken by normal faults, most of which dip toward the Gulf and extend downward many thousands of feet. The earth movements that caused these faults took place within the last 50,000 years. In general, the regional faults in the Houston area trend parallel to the Gulf Coast. Only the local faults over the salt domes show a radial pattern associated with the upthrust of the salt mass. There are numerous faults and fault systems in the Greater Houston and surrounding area. The movements of many of these faults has been affected in recent history by area subsidence.

The subsidence is theorized to have been associated with the removal of oil and groundwater. As much as nine (9) feet of subsidence has occurred in the area east of Houston in the last 70 years. Conversion to surface water usage and the limiting of oil production has greatly reduced the subsidence rate in the area east of Houston.

Figure 3a shows the principal active faults in the Houston area. Figure 3b shows the active surface faults of the Houston area interpreted on LIDAR Imagery (Khan and Engelkemeir). Based on these maps, it does not appear that any known faults are crossing the project alignments.

4.3 Subsurface Soil Stratigraphy and Geotechnical Characterization

***Existing Pavement Material*:** One of the five borings, B-3, is located in existing asphaltic concrete (AC) pavement, it was drilled through using the auger o the drill rig. A summary of the existing pavement sections encountered at each boring location is presented in Table 1.

Based on the pavement information gathered from our field investigation, the existing AC pavement located at Boring B-3 consist of about 6 inches of AC surface over about 6 inches gravel base. The actual pavement material and thicknesses in the field, at or near the boring locations, may differ from those described in Table 1.

***Potentially Hazardous Materials*:** No unusual staining or hydrocarbon-like odor was noted in the soil samples recovered from the soil borings drilled in ATL's geotechnical investigation.

***Subsurface Soil Stratigraphy*:** Based on our soil borings, the subsurface soils along the project alignments consists generally of the following:

Along SWPS Improvements Alignments (Profile 4a): The subsurface soils below the existing AC pavements and ground surface, as found in Borings B-1 through B-5, consist of an upper stratum of stiff to hard Fat Clays (CH) and Lean Clays (CL) that exists to the bottom of the 24-ft deep Boring B-3, and to depths of about 28, 33, 28 and 27 feet in Boring B-1, B-2, B-4 and B-5, respectively. The upper clay stratum is underlain by a stratum of loose to very dense Silty Sands (SM) that exists to the bottom of Boring B-1, B-2, B-4 and B-5 at a depth of 35, 35, 34 and 29 feet below existing grade, respectively.

The detailed subsurface soils and stratigraphy are shown in the individual boring logs in Appendix 3 and in the Boring Log Profile in Figure 4. "CL", "CH" and "SM" are classes of soils described in the Unified Soil Classification System.

The lean clays (CL) found in the soil borings have liquid limits ranging between about 28 and 48%, and plasticity indices (PI) ranging between about 13 and 30%. Clean non-expansive sandy lean clay soils (plasticity index between about 10 and 20) can be used as select fill in their present condition. The fat clay (CH) soils found in the soil borings have liquid limits ranging between about 50 and 79%, and plasticity indices ranging between about 31 and 56%. High plasticity fat and lean clays (PI>20) are not suitable for use as select fill in their present condition; however, these soils in their present conditions may be used as random fill. High plasticity clay soils, if clean, can be treated with appropriate amount of lime and used as select fill; a lime dosage of 6% by weight is recommended for preliminary estimate purposes, but lime vs. pH and/or lime vs. PI series tests should be conducted to determine the optimum lime dosage.

4.4 <u>Groundwater</u>

Free water was encountered during drilling operation in Boring B-1, B-2, B-4 and B-5 at a depth of about 17, 33, 28 and 27 feet, respectively; free water was measured in Borings B-2 and B-4 after 5 minutes at a depth of about 28 and 19 feet, respectively. Boring B-3 was dry during and at completion of drilling operation. Borings B-1 and B-4 were converted into Piezometer PZ-1 and PZ-2 after completion of drilling and soil sampling. Water level in PZ-1 and PZ-2 was measured after 24-hour at a depth of about 14.5 and 17 feet, respectively. Water level in PZ-1 and PZ-2 was measured after 7 days at a depth of about 10.5 and 12.5 feet, respectively. Water level in PZ-1 and PZ-2 was measured after 30 days at a depth of about 10 and 11 feet, respectively.

The groundwater information encountered during and at the end of drilling in the boreholes, and in the piezometer after 24 hours, 7 and 30 days are presented in Table 2. It should be noted that the groundwater conditions will fluctuate according to the amount of precipitation and the environments conditions at the site.

Perched water table may exist in permeable sand/silt lenses/seams/layers within clay stratum that can form pathways for percolated and infiltrated water. The rate of flow of groundwater produced by these layers will depend upon the weather conditions such as locations of size and continuity of the permeable layers/seams/lenses, and the amount of precipitation and ambient temperature etc., at the time of construction.

5.0 GEOTECHNICAL ANALYSES AND RECOMMENDATIONS

The proposed water line installation will involve both open cut and tunneling (trenchless construction) technique. Construction of tunnel shafts/access pits (auger pits) will also involve open cut/trench excavation. Based on the plan and profile drawings, the water lines are proposed to be installed at a depth of about 14 to 20 feet below existing grade.

5.1 OSHA Soil Types

At the federal level, Occupational Safety and Health Act (OSHA) requires protective systems for all trenches exceeding 5 feet in depth. OSHA has developed a soil classification system to be used as a guideline in determining sloping and protective system requirements for trench excavations. This system has set forth a hierarchy of Stable Rock, Type A, Type B, and Type C, in decreasing amounts of stability.

Stable Rock: Natural solid mineral matter that can be excavated with vertical sides and remain intact while exposed.

Type A: Cohesive soils with an unconfined compressive strength of 1.5 ton per square foot (tsf) or greater.

However, no soil is Type A if:

- The soil is fissured; or
- The soil is subject to vibrations from heavy traffic, pile driving, or similar effects; or
- The soil has been previously disturbed; or
- The soil is part of a sloped, layered system where the layers dip into the

excavation on a slope of four (4) horizontal to one (1) vertical or greater; or

- The material is subject to other factors that would require it to be classified as a less stable material.

Type B:

- Cohesive soil with an unconfined compressive strength greater than 0.5 tsf but less than 1.5 tsf; or
- Soil that meets the unconfined compressive strength or cementation requirements for Type A, but is fissured or subject to vibration; or
- Dry rock that is not stable; or
- Material that is part of a sloped, layered system where the layers dip into the excavation on a slope less steep than four horizontal to one vertical (4H:1V), but only if the material would otherwise be classified as Type B.

Type C:

- Cohesive soil with an unconfined compressive strength of 0.5 tsf or less; or
- Granular, including gravel, sand, and loamy sand; or
- Submerged soil or soil from which water is freely seeping; or
- Submerged rock that is not stable;. or
- Material is a sloped, layered system where the layers dip into the excavation on a slope of four (4) horizontal to one (1) vertical or steeper.

Based on the soil conditions from the borings and groundwater information from the borings and piezometers, ATL recommends classifying the top 10 feet of the onsite clay soils (CL/CH) as OSHA Soil Type “B” for the determination of allowable maximum slope or selection and design of the protective system. All onsite clay soils below a depth of 10 feet shall be classified as OSHA Soil Type “C”. Any soft/wet soils, sands (SP/SM/SC), silts (ML), silty clays (CL-ML), and any soils that are saturated or are subject to seepage pressure or vibrations shall be classified as OSHA Soil Type “C”.

5.2 Open Cut/Trench Excavation

The proposed water line installation will involve construction using both open cut/trenching and tunneling (trenchless installation) technique. The approximate flow line depths and the subsurface conditions found in the soil borings are shown in the Boring Log Profile on Figure 4. Accordingly, the water line installation excavation will most likely be advanced in stiff to hard clays (CL/CH).

The trench excavations can be made using cut slopes stepped back to stable slope, vertical cuts supported with sheet piles or other suitably designed retaining system. The excavation should be performed in accordance with the current OSHA 29 CFR Part 1926 of OSHA (Trench Safety System) and City of Houston Standard Specification, Section 02317 – Excavation and Backfill for Utilities.

Trenches should be provided with a proper trench support system. For the trench supporting system, the lateral pressures exerted on trench walls by stiff clays and cohesionless soils are presented in Figure 5a. Where soft to firm cohesive soils are encountered, the lateral pressure may be computed as given in Figure 5b. Where cohesive soils are underlain by sandy soils, the lateral pressure may be computed as given in Figure 5c. Temporary earth retaining walls are sometimes designed assuming an equivalent fluid pressure, in such cases, a lateral earth pressure equivalent imposed by a 84 PCF and 102 PCF fluid is recommended for clay soils above and below the water table, respectively; in sandy soils, a lateral earth pressure equivalent imposed by a 48 PCF and 85 PCF fluid is recommended for soils above and below the water table, respectively. Timber shoring as outlined in 29 CFR Part 1926 of OSHA recommendation may be used in the construction of trench supporting system. Trench boxes are commonly used for trench safety without shoring or bracing in open-cut excavations with vertical walls. In all cases, excavations should conform to OSHA guidelines.

Vehicular and Other Surcharge Loadings: Under normal loading conditions, a surcharge magnitude of q psf can result in lateral earth pressure of about 0.5q in cohesive soils and about 0.4q in sandy soils. All surcharge loads to a distance of 0.5 times the wall height should be considered. Due to the likely presence of roadways along the proposed pipeline alignment, the effects of vehicular traffic should be considered while designing the lateral supporting systems. The highway loading imposed by a H20 truck on a pipe under various depths of soil cover is presented in Figure 6. Figure 7 presents Boussinesq's equation for computing both horizontal and vertical stresses imposed by a surface surcharge load.

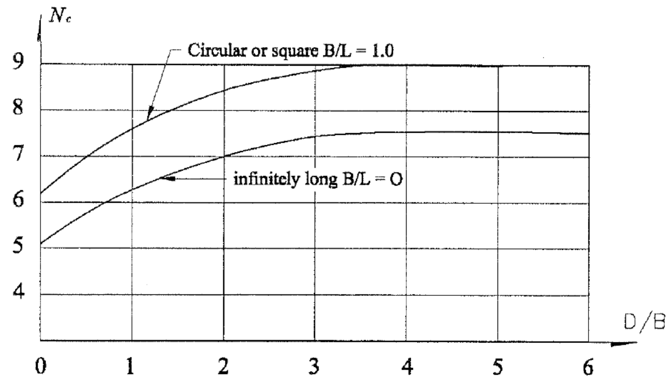
Stockpiling of excavated material should not be allowed near the excavation. Generally, a distance of at least one-half the excavation depth on both sides of the trench should be kept clear of any excavated material and height of stockpile should be limited to no more than 3 feet. If this is not possible due to space limitations then the retaining system design should be designed to take into account the surcharge loads.

In stable cohesive soils and where groundwater is lowered at least 3 feet below the excavation bottom, and if the sheeting terminates at the base of cut, the trench bottom stability can be evaluated in the following manner:

$$\text{Factor of safety } (F_s) = \frac{(N_c)\ C}{(\Upsilon)\ D + q}$$

Where,

N_c = Bearing capacity factor that depends on dimensions of the excavation:



N_c rectangular = $(0.84 + 0.16B/L)N_c$ square

C = Average undrained shear strength of clay in failure zone beneath and surrounding base of cut, psf.

ϒ' = Average effective unit weight of soils above trench bottom, pcf.

q = Surface surcharge, psf.

D = Depth of trench, ft.

L = Length of trench, ft.

B = Width of trench, ft.

If the factor of safety is less than 1.5, sheeting should be extended below the base of the cut to insure stability. The extended sheeting depth should be at least 1.5 times the trench width.

5.3 Groundwater Control

Groundwater information gathered from the soil borings during, after about 5 minutes, and at completion of drilling, as well as the after 24 hours, 7 and 30 days water level readings in the piezometers are presented in Section 4.4. It should also be noted that groundwater levels will fluctuate as a result of seasonal rainfall variations.

The approximate flow line depths and the subsurface conditions as found in the soil borings are shown in the Boring Log Profile on Figure 4. Based on the proposed invert elevation and the groundwater information gathered during our field investigation, the water line construction excavations will likely to encounter groundwater when the excavation depths approaches or exceeds about 10 feet. It should be noted that groundwater level will fluctuate with the amount of precipitation and the prevailing environmental conditions prior to and during construction.

Seepage rate in clay soils, if exists, will likely be low, but seepage rate in sands (if exists) will be higher. Groundwater control for excavation in cohesive soils up to a depth of 15 feet, if required, can usually be accomplished by sump and pump arrangements because the seepage is relatively slow. For dewatering below the depth of about fifteen (15) feet multi-staged pumps will be required. When excavations extend into water-bearing sands/silts (not found in soil borings drilled in this investigation, but may be present away from the borings drilled or after heavy rainfalls), then dewatering using well points will be necessary. Criteria and requirements of City of Houston Standard Specification, Section 01578 – Control of Ground Water and Surface Water should be followed.

Seams and pockets of sand, silt, ferrous nodules, and calcareous nodules that may exist in cohesive soil layers may form communicative drainage paths for the groundwater, leading to potential water-bearing/perched water condition, and as a result, accelerated the rate of seepage. If such phenomenon is observed during the trench excavation and construction, appropriate measures, such as proper dewatering and shoring methods, may have to be implemented under supervision of a Professional Civil/Geotechnical Engineer.

5.4 <u>Bedding Criteria</u>

Where water line is installed using open cut method, the trench bottom for water line placement should be over-excavated to a minimum of 12 inches. For auger/tunnel pits the over excavation should be to a minimum of 6 inches. The space should be filled with bank sand to a depth of at least 12-inches above the pipe top and compacted to a minimum of 95 percent of the Standard Proctor

(ASTM D 698) maximum dry density at a moisture content between -3 to +5 percent of the optimum moisture content. The trench bottom should be shaped to receive the water pipe. The bedding details should be in accordance with the latest City of Houston Construction Details. City of Houston Drawing No. 02317-04 should be used for the water main bedding and backfill. The bedding and backfill for auger pit, if any, should be in accordance with City of Houston Drawing No. 02447-01.

Soft and/or wet soils, if encountered at trench bottom, should be handled according to requirements specified in City of Houston Standard Specifications Section 02317, Subsection 3.07, A and B.

5.5 Trench Backfill

The backfill should conform to standard City of Houston Specification, Section 02317 – Excavation and Backfill for Utilities. The backfill materials should conform to standard City of Houston Specification, Section 02320 – Utility Backfill Materials.

The embedment material between the pipe and the trench (bedding, haunching and initial backfill) may consist of bank run sand placed in maximum six-inches compacted lift thickness and compacted to a minimum of 95 percent of the maximum dry density as determined by Standard Proctor test (ASTM D698) at –3 to +5 percent of the optimum moisture content.

In the trench zone within the pavement area, the backfill may consist of bank run sand or select fill. The bank run sand should be placed in maximum 12 inches loose lift thickness and compacted by vibratory equipment to a minimum of 95 percent of the maximum dry density at moisture content within zero percent to -3 and +5 percent of optimum as determined by ASTM D698. The select fill may be placed in maximum 6-inch compacted lift thickness and compacted to a minimum of 95 percent of the maximum dry density at moisture contents within 0 and +5 percent of optimum as determined according to ASTM D 698. The cut pavement should be replaced to match the existing pavement type and the thickness should be equal or greater then the existing pavement thickness.

The finished pavement surface must be even with existing pavement elevation. In the trench zone outside the pavement area, a random backfill of suitable material (clayey soils) may be used. The random backfill may be placed in maximum 12 inches loose lift thickness for clayey soils and compacted to a minimum of 90 percent of the maximum dry density as determined by ASTM D 698 at moisture content necessary to achieve the density.

5.6 ***Loads on Buried Conduits***

The pipelines placed at depths under the ground will be subject to loads due to backfill (earth loads) and loads due to vehicular traffic (live loads).

Earth Load: The earth loads on a buried pipe can be calculated based on Marston's formulae (Ref: 1 through 3). The Marston's equation for buried conduits are generally given as:

$$W_d = C_d \Upsilon B_d^2 \qquad \text{- for rigid pipes}$$

$$W_d = C_d \Upsilon B_d B_c \qquad \text{- for flexible pipes}$$

Where,
- W_d = fill load, in pounds per linear foot of pipe
- C_d = Marston's soil coefficient
- Υ = Unit weight of fill material, pcf (use 120 pcf)
- B_d = Width of trench at or slightly below top of pipe, in feet
- B_c = Width of pipe, in feet

The above equation is valid when the conduit is placed in a trench not wider than 2.0 to 3.0 times its outside width. Marston's soil coefficient C_d can be obtained from Table 4. K is the active earth pressure coefficient and μ is the coefficient of sliding friction between the fill material and the sides of the trench. The height of fill and the horizontal width of trench should be considered from the top of the conduit. For the above equation for flexible pipes, an assumption of equal stiffness of soil and pipe has been used for its development and the equation generally gives a minimum load value.

Hence, for flexible pipes including ones installed using trenchless construction, the earth loads may be conservatively calculated using the prism load theory. The prism load (Ref: 1 through 3) determines the weight of the soil column directly above the pipe and neglecting factors such as side wall friction and/or the cohesion of the soils. The prism load (in psf) may be calculated by multiplying the total unit weight of soil above the pipe (say 120 pcf) by the height, H (ft) of the soil fill. The prism load generally gives higher loading on the pipe and simulates the long term load imposed on the pipe.

<u>Vehicular Load</u>: For calculation of live loads, the width of the loaded area should be taken as the outside horizontal width of the pipe. Loading due to H20 vehicle should be considered for vehicular traffic. The estimated highway loading on a buried conduit imposed by a H20 truck, under various soil cover, is presented on Figure 6.

<u>Surcharge Load</u>: The stresses imposed by a surcharge load can be estimated using Boussinesq's Equation presented on Figure 7.

5.7 Tunneling/Trenchless Construction

Part of the proposed water lines will be installed using tunneling/trenchless construction technique. Tunneling techniques including tunnel boring machine (TBM), microtunneling, etc. may be employed. Tunneling construction of the water line shall be in accordance with applicable requirements in City of Houston Standard Specifications Section 02425 “Tunnel Excavation and Primary Liner”, Section 02511 “Water Lines”, and, Section 02517 “Water Line in Tunnels”, and other applicable specifications.

Augering is one of the trenchless technique, it may involve dry auger or slurry auger method. In the dry auger method, the casing is advanced by jacking while soils are excavated at the advancing end of the casing. In the slurry auger method, a small diameter pilot hole is first drilled between the access shafts, followed by reaming the pilot hole to full diameter by augering with slurry and installing casing or pipe by pull-back or jacking techniques. Requirements of City of Houston Standard Specification, Section 02447 – Augering Pipe and Conduit, should be followed.

The water line will be installed mostly in stiff to hard clays, in which case the excavation face are anticipated to be stable. Groundwater conditions observed in open boreholes during the field investigation and in piezometers are presented in Section 4.4.

Although not encountered in our soil borings, excavation face in granular soils (sand/silt/gravel), clay soils with slight/low plasticity or containing a significant amount of sands, and other caving soils, if encountered at/near the excavation face, will likely to experience some degree of instability if the excavation face is unsupported, especially when these soils are saturated and/or subject to seepage pressure. In such cases, the following mitigating measures can be employed to improve the excavation stability:

1) Lower the groundwater table to at least 3 feet below the excavation bottom, and use colloidal drilling fluid (usually bentonite slurry) under controlled pressure to improve stability of the excavation.
2) In conditions where mitigation measures employed in Item 1 above cannot adequately provide the excavation stability, a casing can be installed at the same time of the slurry augering to provide stability of the excavation and reduce settlement at the surface.
3) In ground conditions where highly unstable soils and/or high inflow rate/pressure exist, microtunneling machine equipped with face shield and pressure-balancing colloidal drilling fluid may be used to maintain the stability of the excavation face.
4) Alternatively, open cut with shoring or other methods approved by City of Houston Department of Public Works and Engineering, along with groundwater control, and other stabilizing techniques such as chemical grouting, may be used at locations with difficult subsurface conditions or site constraints.

It is the responsibility of the Contractor to select a trenchless technique for the installation of the proposed water line by taking into account the soil types and stratigraphy and the groundwater conditions as found in the soil borings; the Contractor should have a work crew experienced in working with the selected trenchless construction technique in subsurface conditions similar to those found along the project alignments. If necessary, the Contractor may conduct additional geotechnical investigation to provide more detailed subsurface conditions.

Auger pit construction criteria provided in City of Houston Standard Specification, Section 02447 – Augering Pipe and Conduit, should be followed. Tunnel shaft construction should be in accordance with City of Houston Standard Specifications Section 02400 "Tunnel Shafts". Shoring systems for the auger pits and tunnel shafts may be designed based on the lateral earth pressures and other considerations discussed in Section 5.2.

5.8 Effects of Trenchless Construction on Surrounding Structures

A properly designed and controlled trenchless construction operation can reduce immediate soil movement and subsidence to a tolerable level. Nevertheless, some ground loss should be expected during any trenchless construction operations. With good construction techniques, ground loss can be mitigated to acceptable levels. Trenchless construction below pavement and buried utilities may lead to some future settlement due to loosening of the subgrade or bedding condition. Large ground loss can result from uncontrolled flowing ground. Such conditions may occur if water-bearing sands or silts were encountered (not encountered in our soil borings, but may be present away from the borings drilled) in the excavations along the trenchless construction alignment. Measures to mitigate ground loss and other impacts of trenchless construction were addressed in Section 5.7.

The zone of influence of the augering/tunnel roughly extends to a distance equal to the invert depth on each side of the centerline of the trenchless construction alignment. The amounts of settlement due to trenchless construction are difficult to estimate. We anticipate that if good construction practices and control are exercised, the amount of ground settlements should be small. Establishing monitoring points on existing roadways, buildings and other important structures along the trenchless construction alignments, and record coordinates and elevations prior to, during and after construction to monitor the amount of settlements or lateral movements due to trenchless construction, and adjust trenchless construction technique accordingly to mitigate the movements as necessary. Existing damages to the surrounding structures should be documented prior to starting of the trenchless construction operations.

5.9 Thrust Restraint

Unbalanced thrust forces result from changes in flow directions and/or velocity in a pressurized pipe system (see Figure 8). The unbalanced thrust force and magnitude of thrust block force T is defined as follows:

$$T = 2\ PA\ \text{Sin}\ (\theta/2)$$

Where, P = internal fluid pressure (psi);

A = cross-sectional area of pipe (in^2);

θ = deflection angle of bend; and,

T = thrust force (pounds)

Adequate restraint may be achieved by using thrust blocks, restraint joints, tie rods, or a combination of these systems. The unbalanced force acting on a pipe system is transmitted by a thrust block and resisted by the bearing area between the pipe and the foundation soils. The unbalanced force acting on a pipe system with restraint joints are resisted by the frictional forces between the pipe/soil interface across the pipe sections restrained to act integrally.

Thrust Blocks: Thrust blocks are commonly used to increase the bearing area to allow the fittings to resist movement. The procedures for thrust block design are given in detail in AWWA M9 (Ref. 1). The required thrust block bearing area is calculated based on the bearing capacity of the soil:

$$\text{Required Bearing Area of Thrust Block} = T/F$$

Where,	T	=	thrust force (lb); and,
	F	=	safe bearing value for soil (lb/sq.ft)

A safe bearing value of 1,500 psf can be used for thrust block design bearing on compacted soils. This value includes a factor of safety of 3. The blocks must be placed against undisturbed or compacted soils and the face of the block must be perpendicular to the direction of and centered on the line of action of the thrust. Proper care must be exercised after construction to prevent failure due to any future excavations behind the blocks.

Restrained Joints: Restrained joints are typically used to avoid the uncertainties of thrust blocking like future excavations, etc. A detailed procedure for designing restrained joints including example calculations is outlined in the AWWA design manual M9 (Ref. 1). The following soil parameters are recommended for the design of the restrained joint(s):

Average unit weight of soil, γ	= 120 pcf	
Cohesion of soils, C	= 250/500/1000 psf	(for soft/firm/stiff clays)

For coefficient of friction between pipe and granular soils, f, use 0.25 for smooth PVC and steel pipes, and use 0.3 for concrete pipes.

5.10 Flexible Pipe Deflection

The deflection of a flexible pipe may be determined using the modified Iowa formula of Watkins and

Spangler (Ref. 2) as given below:

$$\Delta x = D_l \left[KWr^3 / (EI + 0.061\, E' r^3) \right]$$

Here EI is the pipe wall stiffness (in-lb.), r is the radius (in.) and W is the load per unit of pipe length (lb/in. in. of pipe). Where prism loads (i.e. weight of soil above the pipe) are used for pipe earth loads, a deflection lag factor, D_l of 1.0 may be used. Otherwise, deflection lag factor, D_l of 1.5 should be used. The bedding constant, K, may be taken as 0.1. The following typical soil parameters are recommended:

Soil Type	Soil Consistency	Unit Weight, pcf	Shear Strength (c), psf or SPT Blow Counts, blows/ft	Modulus of Soil Reaction, psi/in
Fat Clays and Lean Clays	Soft	120	$c \leq 250$	100
	Firm	124	$c \leq 500$	300
	Stiff	128	$c \leq 1{,}000$	600
	Very Stiff	130	$c \leq 2{,}000$	1,000
	Hard	132	$c > 2{,}000$	2,000
Granular Soils: Sands, Silts and Gravel	Loose	110	$2 \leq N_{SPT} \leq 7$	300
	Loose to Medium Dense	113	$8 \leq N_{SPT} \leq 15$	600
	Medium Dense	115	$16 \leq N_{SPT} \leq 30$	1,000
	Dense	118	$N_{SPT} > 30$	2,000

* Buoyant soil unit weight is computed by subtracting unit weight of water from the soil unit weight

5.11 <u>Buoyant Uplift</u>

Portion of a buried structure located below the water table is subject to an upward hydrostatic pressure, called the *buoyant uplift pressure*. Resistance to buoyant uplift pressure is provided by the following components:

- *Weight of the structure (W)*
- *Weight of the soil above the base extension beyond the wall(Ws)*
- *Frictional force between the soil and foundation (Fs).*

Buoyant Uplift Resistance = W + Ws + Fs

W and Ws are can be readily computed. The computation of the buoyant uplift, and the skin friction resistance are shown in Figure 9. If base extension option is used, we recommend using a buoyant unit weight of backfill soil above the base extension of 65 pcf when computing Ws.

5.12 Street Cut and Repair

Any street cut necessary for this project should be restored to its original condition using material similar in nature and thickness to the existing streets. Recommendations outlined in City of Houston Standard Specification, Section 02951 – Pavement Repair and Resurfacing should be followed. The top 8 inches of the subgrade soils in the pavement repair areas should be stabilized. ATL recommends stabilizing subgrade clay soils with plasticity indices above 15 and above 25 with at least 6 and 7 percent lime, respectively, and stabilizing granular soils and clay soils with plasticity indices of less than 15 with at least 4 percent lime and 8 percent fly ash, on a weight basis; optimum amount of stabilization shall be determined by conducting laboratory testing.

The lime and lime-fly ash stabilization should be carried out in accordance with City of Houston Standard Specifications Section 02336 and 02337, respectively.

6.0 CONSTRUCTION CONSIDERATION

The proposed water line installation will involve mostly trenchless construction techniques and some open cut/trenching construction. Accordingly, the water line installation excavations will be installed mostly in stiff to hard clay soils with local areas of soft to firm stratum.

Although not encountered in our soil borings, excavation face in granular soils (sand/silt/gravel), soils with only slight plasticity and other caving soils, if encountered, will likely to experience some degree of instability if the excavation face is unsupported, especially when these soils are saturated and/or subject to seepage pressure. In such cases, mitigating measures as discussed in Section 5.7 of this report can be employed to improve the excavation stability.

Based on the proposed invert elevation and the groundwater information gathered during our field investigation, the proposed water line construction excavations will likely to encounter groundwater when the excavation depth approaches or exceeds about 10 feet. However, it should be noted that groundwater level will fluctuate with the amount of precipitation and the amount of precipitations prior to and during construction. For water line installation excavation advanced in clay soils, the seepage rates are usually low, and groundwater control can usually be controlled by sumping and pumping. However, for excavations advanced in water-bearing sands/silts stratum (not encountered in our soil borings, but may be present away from our soil borings and/or after heavy rainfalls), where water inflow rate is high, dewatering using well points will be required to provide a dry working platform and to prevent soil boiling.

It is the responsibility of the Contractor to select a trenchless technique for the installation of the proposed water line by taking into account the soil types and stratigraphy and the groundwater conditions as found in the soil borings; the Contractor should have a work crew experienced at working with the selected trenchless construction technique in subsurface conditions similar to those found in along the project alignments. If necessary, the Contractor may conduct additional geotechnical investigation to provide more detailed subsurface conditions.

6.1 Quality Control

Associated Testing Laboratories, Inc. (ATL) recommends implementation of a comprehensive quality control program under the supervision of a Professional Engineer due to the fact that a considerable amount of excavation and back filling may be required in the proposed project area. Structural integrity and stability is particularly dependent on quality foundation installation, bedding and subgrade preparations. An independent testing laboratory should be assigned to test and inspect construction materials during the construction phase.

To ensure that excavation will remain stable, to provide sufficient headroom for working, to provide worker's safety and to protect adjacent structures, the excavations will have to be provided with sufficient side slopes or shored in accordance with OSHA "Trench Safety Systems" (29 CFR Part 1926), as published in the Federal Register, Vol. 52, No.72, Section 1926-650 through 1926-653. Excavation of the trenches and access pits should be carried out under the supervision of an experienced construction supervisor and necessary shoring and/or bracing of the trenches should be properly installed. In temporary braced or shored excavations and in access pits where the sheeting terminates at the base of the trench, lateral earth pressure, surcharge, and seepage pressure caused by a differential hydrostatic head moving upward to the bottom of the trench can cause trench bottom instability. Therefore, it is recommended that, if the bottom stability evaluation yields a factor of safety less than 1.5, the sheeting should be extended below the base of cut. Before filling operations take place, representative samples of the proposed fill material should be tested by an independent laboratory to determine the compaction and classification characteristics.

6.2 Monitoring

Despite the thoroughness of this geotechnical exploration, there is always the possibility that actual subsurface conditions may differ from the predicted conditions because conditions between soil borings can be different from those at specific boring locations.

Any excessive ground movements like settlement and lateral movement should be monitored and controlled. This can be done by performing a preconstruction survey including photography and documentation of existing conditions like elevations, cracks, etc., and by installing ground movement monitoring devices such as inclinometers, crack monitors, and establishing elevation monitor stations along the waterline alignment to monitor the ground movement after commencement of the excavation.

Associated Testing Laboratory, Inc. (ATL) recommends a regular inspection and overall project monitoring by a geotechnical engineer during the construction phase. The purpose of inspection is to provide sound engineering and judgement alternatives during construction, if unanticipated conditions occur.

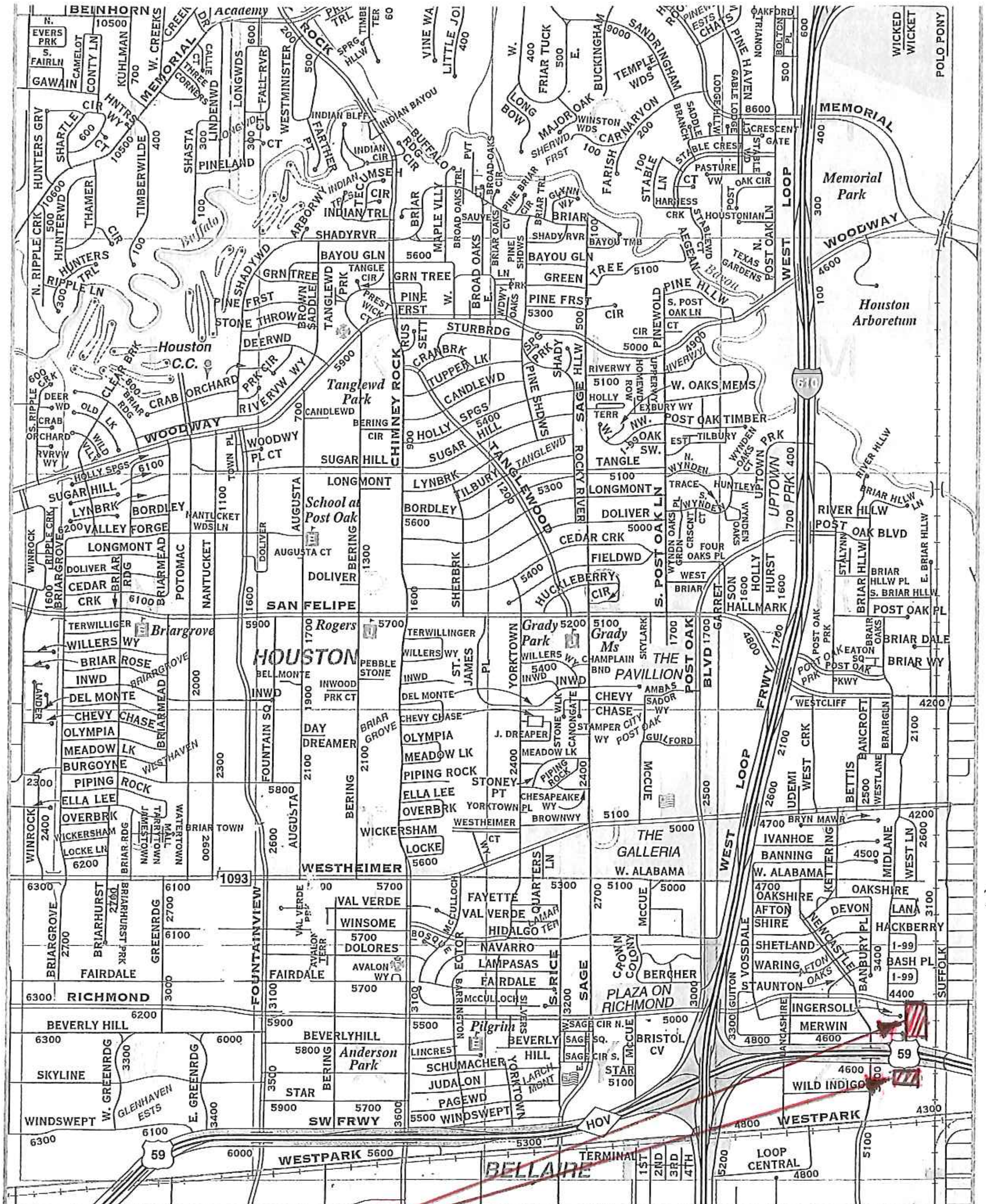
7.0 __LIMITATIONS__

The information, findings and recommendations contained in this report are based on data obtained from test borings at the locations shown in Figure 2, a reasonable volume of laboratory tests, and professional interpretation and evaluation of the field and laboratory data, and consideration of the project information furnished. Should it become apparent during construction that soil conditions differ significantly from those discussed in this report, this office should be notified immediately so that further evaluation and any necessary adjustments can be made.

8.0 REFERENCES

1. "Concrete Pressure Pipe"; Manual of Water Supply Practices – American Water Works Association (AWWA).
2. "Steel Pipe – A Guide For Design And Installation"; Manual of Water Supply Practices American Water Works Association (AWWA).
3. A. P. Moser (1990), Buried Pipe Design, McGraw-Hill, Inc.
4. Joseph E. Bowles (1982), Foundation Analysis and Design, 3rd ed., McGraw-Hill Book Company.
5. Braja M. Das (1985), Principles of Geotechnical Engineering, PWS Engineering.
6. Merlin G. Spangler and Richard L. Handy (1982), Soil Engineering, Fourth Edition, Harper & Row *Publishers.*
7. Alfreds R. Jumikis (1971), Foundation Engineering, Intext Educational Publishers.
8. Policy, Criteria and Procedure Manual (PCPM) – Appendix D, HCFCD 2004.
9. Annual Book of ASTM Standards for Soils and Rock; Building Stones.
10. Harris County Soil Survey; USDA Soil Conservation Services.
11. Geologic Atlas of Texas; Bureau of Economic Geology, The University of Texas.
12. Groundwater Quality in Texas; Texas Natural Resources Conservation Commission.
13. CFR PART 1926.

LIST OF FIGURES



SITE LOCATION

SITE VICINITY MAP

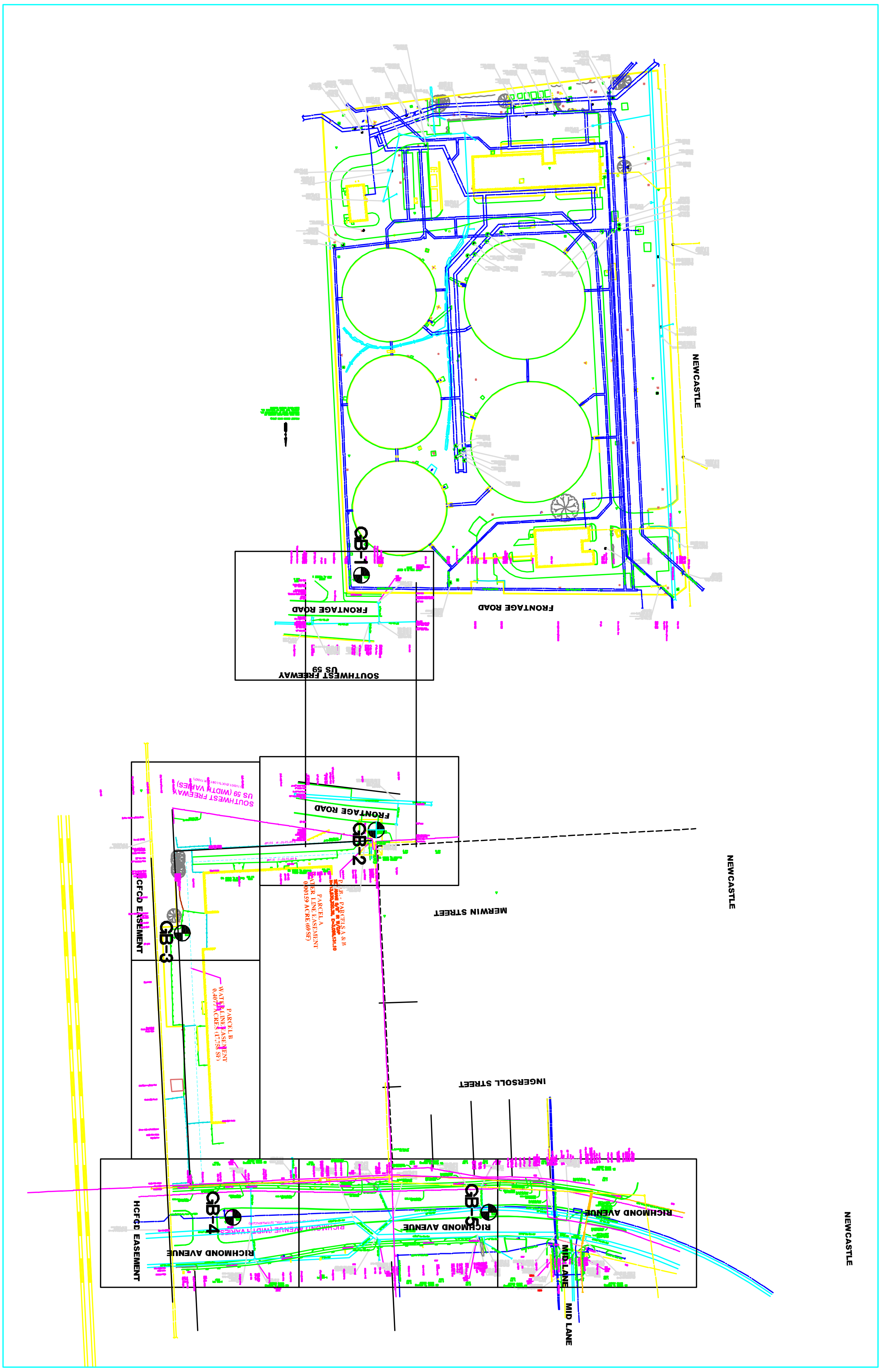
Associated Testing Laboratories, Inc.
3143 Yellowstone Blvd. Houston, Texas
Tel: (713) 748-3717 Fax: (713) 748-3748

PROPOSED SOUTHWEST PUMP STATION IMPROVEMENTS-PACKAGE II

WBS No.: S-001000-0047-3

PROJECT NO. G13-225

FIGURE. 1



LOCATION OF BORINGS

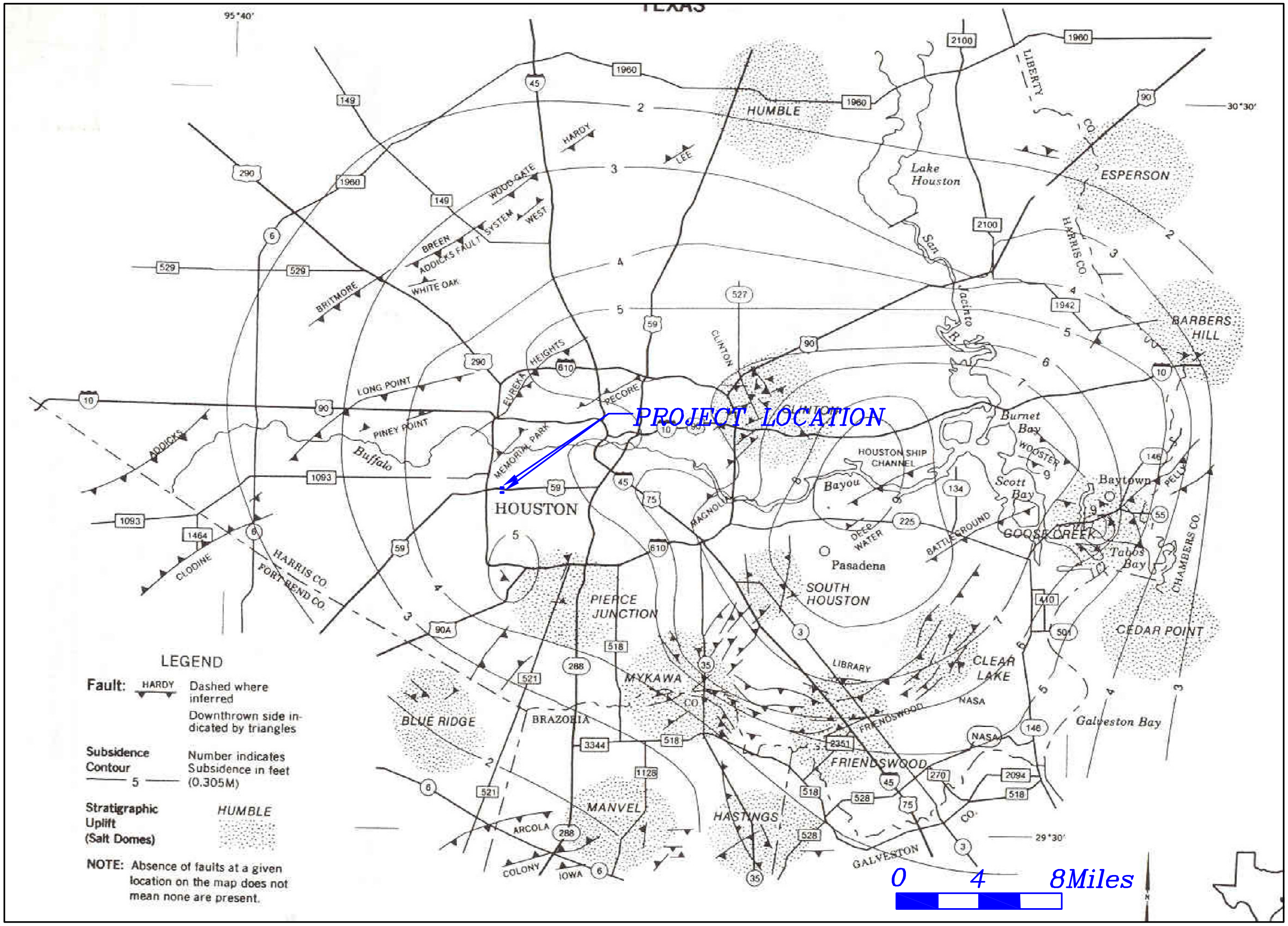
Associated Testing Laboratories, Inc.
3143 Yellowstone Blvd. Houston, Texas
Tel: (713) 748-3717 Fax: (713) 748-3748

PROPOSED SOUTHWEST PUMP STATION IMPROVEMENTS-PACKAGE II

WBS No.: S-001000-0047-3

PROJECT NO. G13-225

FIGURE. 2



PRINCIPAL ACTIVE FAULTS IN HOUSTON AREA

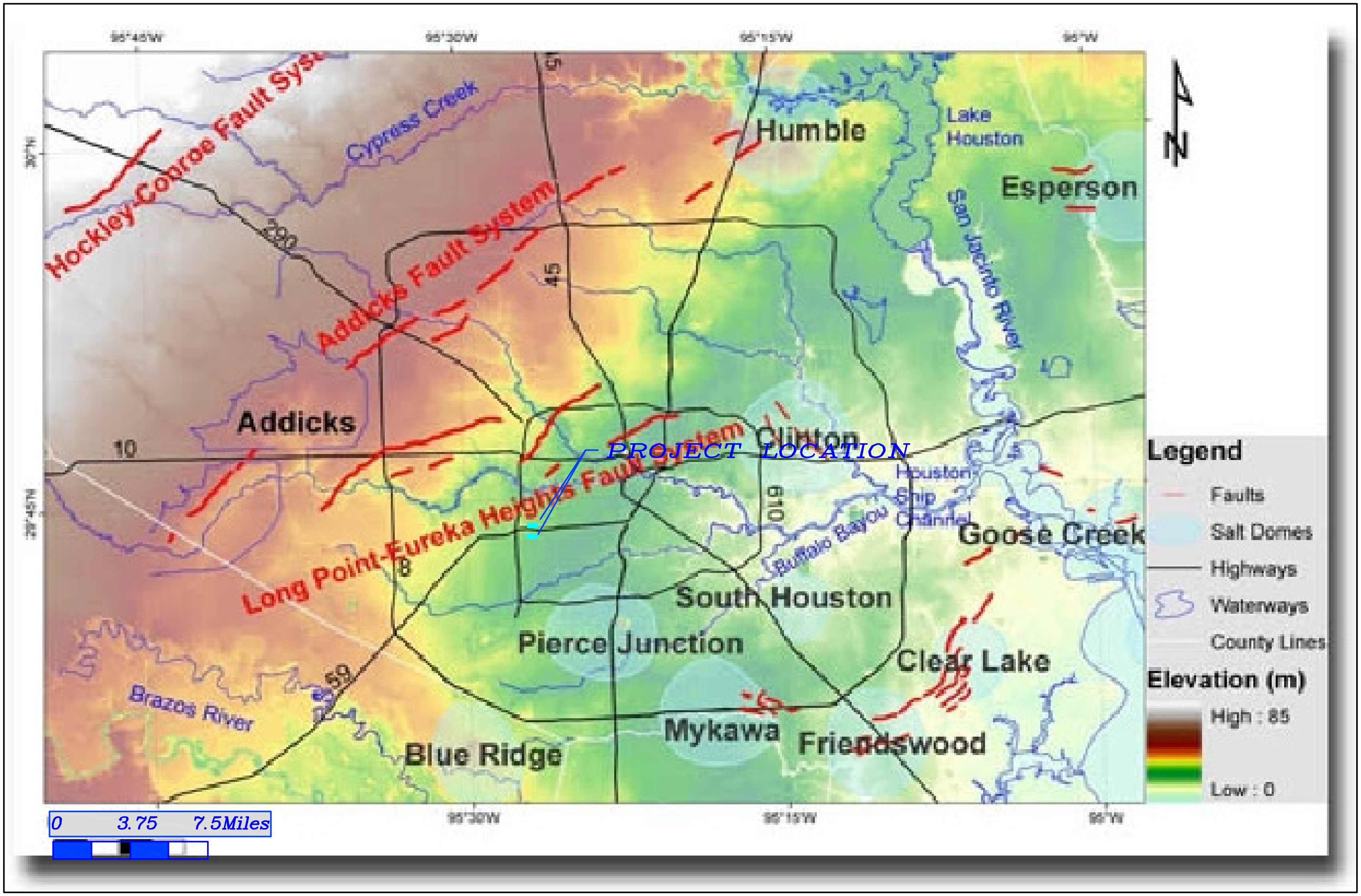
PROPOSED SOUTHWEST PUMP STATION IMPROVEMENTS–PACKAGE II

Associated Testing Laboratories, Inc.
3143 Yellowstone Blvd. Houston, Texas
Tel: (713) 748–3717 Fax: (713) 748–3748

WBS No.: S–001000–0047–3

PROJECT NO. G13–225

FIGURE. 3a

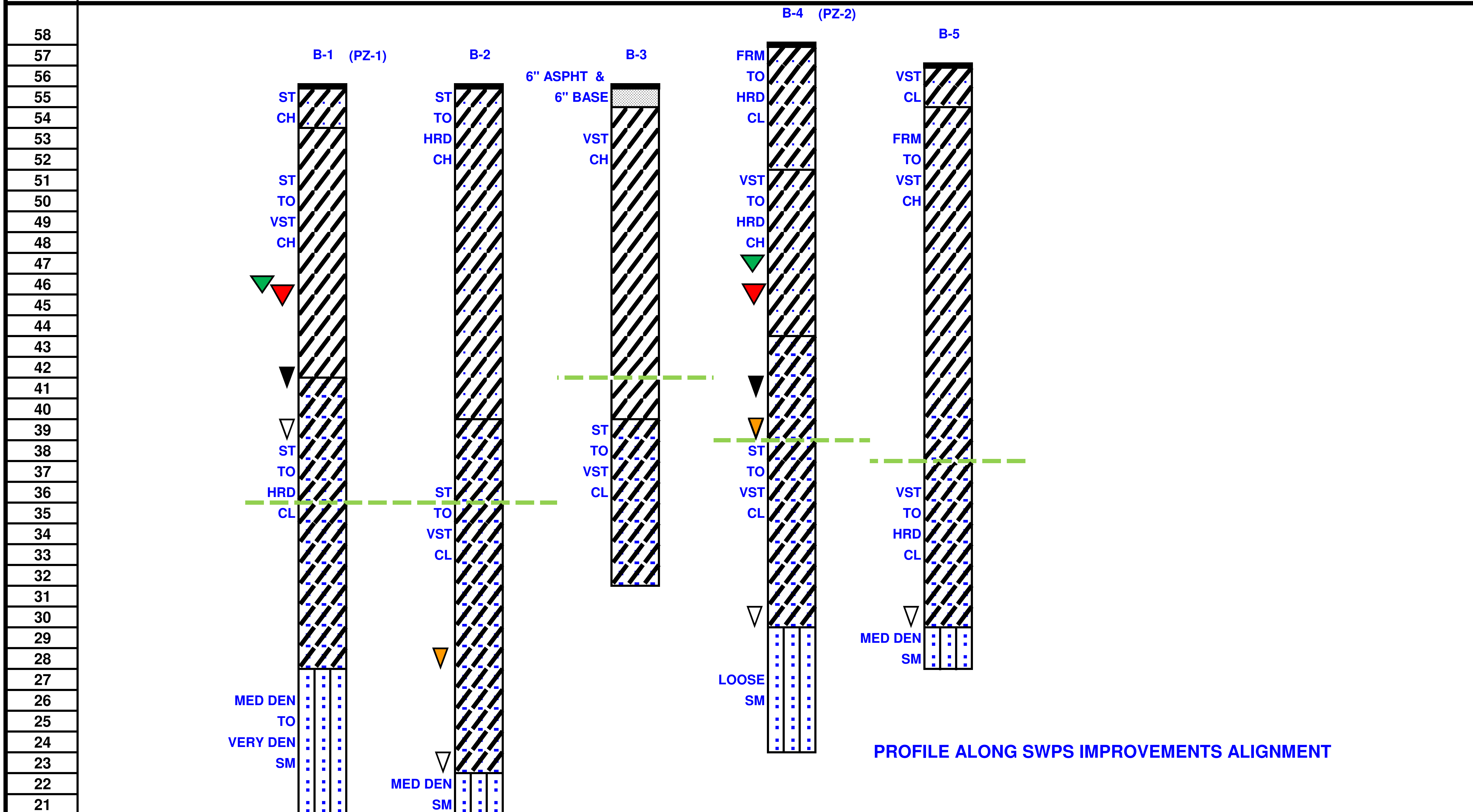


ACTIVE SURFACE FAULTS ON LIDAR IMAGERY	Associated Testing Laboratories, Inc. 3143 Yellowstone Blvd. Houston, Texas Tel: (713) 748-3717 Fax: (713) 748-3748
PROPOSED SOUTHWEST PUMP STATION IMPROVEMENTS-PACKAGE II	WBS No.: S-001000-0047-3
	PROJECT NO. G13-225 FIGURE. 3b

ASSOCIATED TESTING LABORATORIES, INC.

PROJECT NAME: PROPOSED SOUTHWEST PUMP STATION IMPROVEMENTS - PACKAGE II

Elev. WBS No. S-001000-0047-3 PROJECT NO.: G13-225



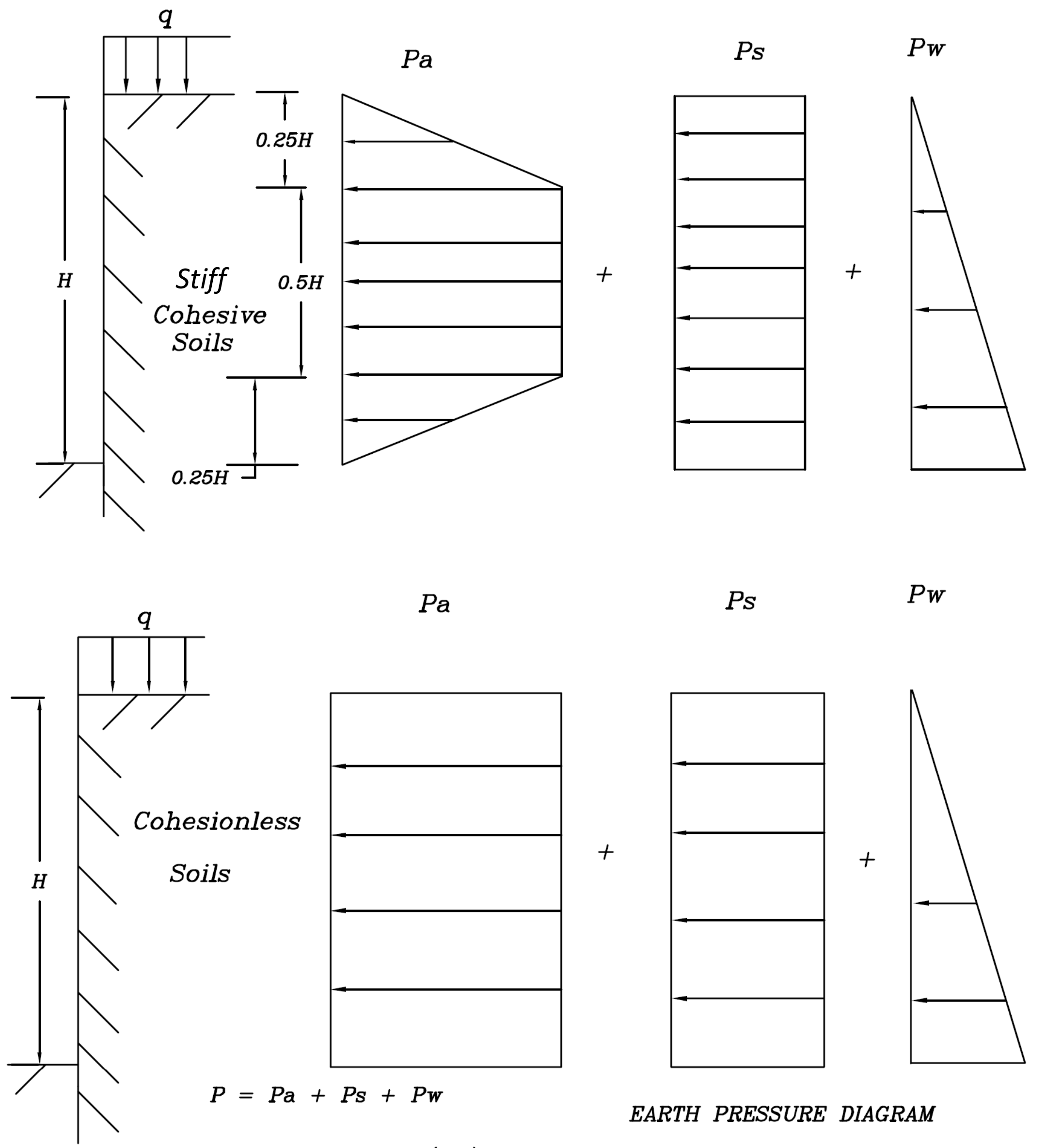
Symbol	Legend
▽	Water First Noticed
▼ (orange)	Depth To Water At 5 minutes
▼	24 hr. Water Level
▼ (red)	PZ Water Level (11-14-13)
▼ (green)	PZ Water Level (12-6-13)

KEY

CH- Fat Clay		ST - Stiff
CH- Fat Clay With Sand		VST - Very Stiff
CL- Lean Clay With sand		FRM - Firm
CL- Sandy Lean Clay		HRD - Hard
SM- Silty Sand		MED DEN - Medium Dense

SCALE
Horizontal: N.T.S.
Vertical : 1"=5'

Figure-4



Where P = Total lateral pressure (psf)

Pa = Active earth pressure(psf) = $K_A \gamma H = 0.4\gamma H$ for Stiff Clays

= $0.65\ K_A \gamma H = 0.25\gamma H$ for cohesionless Sands ($0.33\gamma H$–for loose sand)

Ps = Lateral pressure due to surcharge load (psf) = $0.5q$ for Clays

= $0.4q$ for Sands

($0.5q$ for loose Sands)

Pw = Hydrostatic pressure (psf) = 62.4* water depth

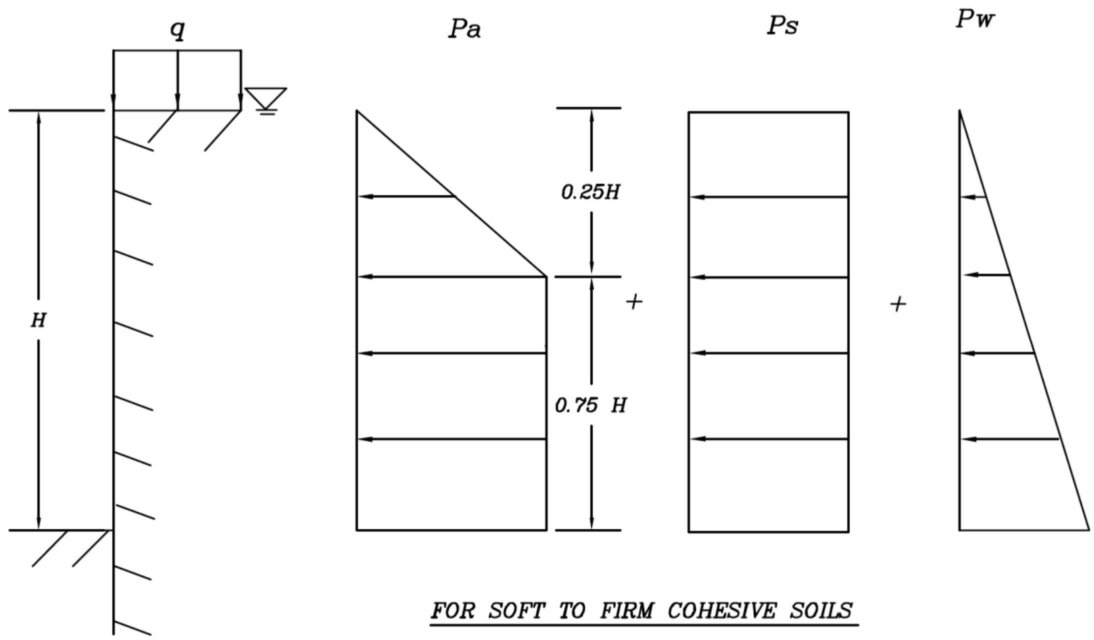
H = Depth of braced excavation (ft)

q = Surcharge load (psf) usually taken as 500 psf

γ = Submerged density of soils (pcf) = use 60 pcf (use 50 pcf for loose Sands)

Source: Peck, R.B. 1969. "Deep Excavations and Tunneling in Soft Ground".

EARTH PRESSURE DIAGRAM	ASSOCIATED TESTING LABAORATORIES, INC. 3143 YELLOWSTONE BLVD., HOUSTON, TEXAS TEL: (713) 748-3717 Fax: (713) 748-3748	
SOUTHWEST PUMP STATION IMPROVEMENTS – PACKAGE II	WBS NO. S-001000-0047-3	
	PROJECT NO. : G13-225	FIGURE 5a



FOR SOFT TO FIRM COHESIVE SOILS

Where P = Total lateral pressure (psf)

Pa = Active earth pressure(psf) = $1.0 K_a \gamma H$ for soft clays

K_a = Active Earth pressure coefficient

$= 1 - m \dfrac{2 q_u}{\gamma H} = 1 - m \dfrac{4C}{\gamma H}$ (taking $C = \dfrac{q_u}{2}$)

Here $m=1$ for $N<4$ and $m=0.4$ for $N>5$

N = Stability number $= \gamma H/C$

Ps = Lateral pressure due to surcharge load (psf) = K_a for clays

Pw = Hydrostatic pressure (psf) = 62.4* water depth

H = Depth of braced excavation (ft)

q = Surcharge load (psf) usually taken as 500 psf

γ = density of soils (pcf) = use 50 pcf below groundwater and 110 pcf above groundwater

q_u = Unconfined compressive strength, psf

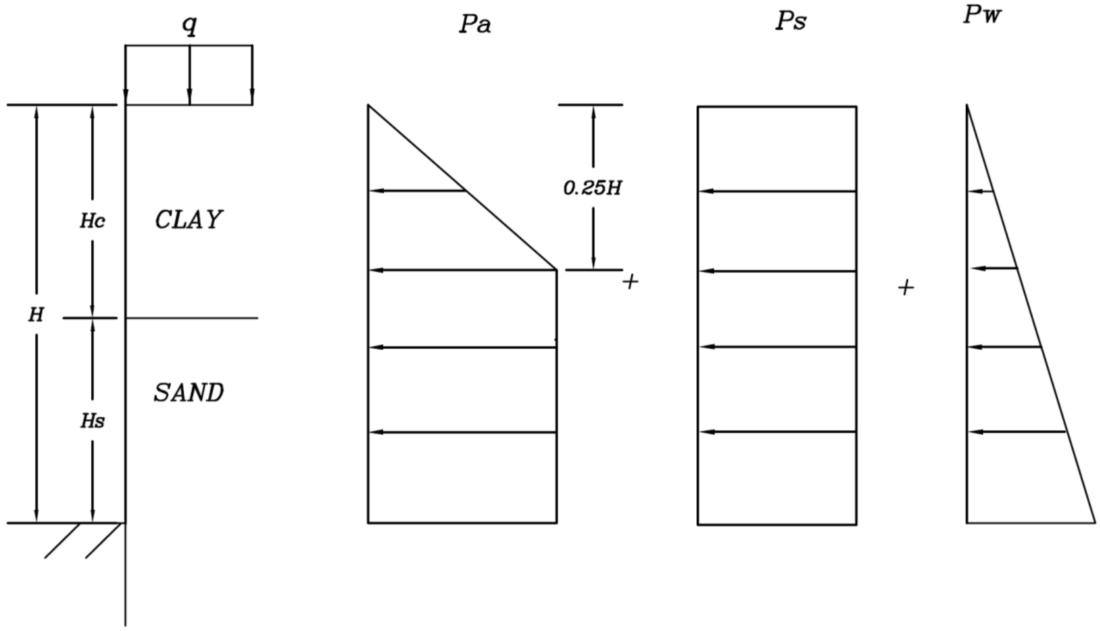
C = Undrained shear strength, psf

Note: Neglect hydrostatic pressure above groundwater level

Source: Peck, R.B. 1969. "Deep Excavations and Tunneling in Soft Ground".

EARTH PRESSURE DIAGRAM	ASSOCIATED TESTING LABAORATORIES, INC. 3143 YELLOWSTONE BLVD., HOUSTON, TEXAS TEL: (713) 748-3717 Fax: (713) 748-3748
SOUTHWEST PUMP STATION IMPROVEMENTS – PACKAGE II	WBS NO. S-001000-0047-3 PROJECT NO. : G13-225 — FIGURE 5b

PST 8/28/12



$$P = Pa + Ps + Pw$$

Where P = *Total lateral pressure (psf)*

Pa = *Active earth pressure(psf)* = $K_A \gamma H = 0.4 \gamma H$

Ps = *Lateral pressure due to surcharge load (psf)* = $0.5q$

Pw = *Hydrostatic pressure (psf)* = *62.4* water depth*

H = *Depth of braced excavation (ft)*

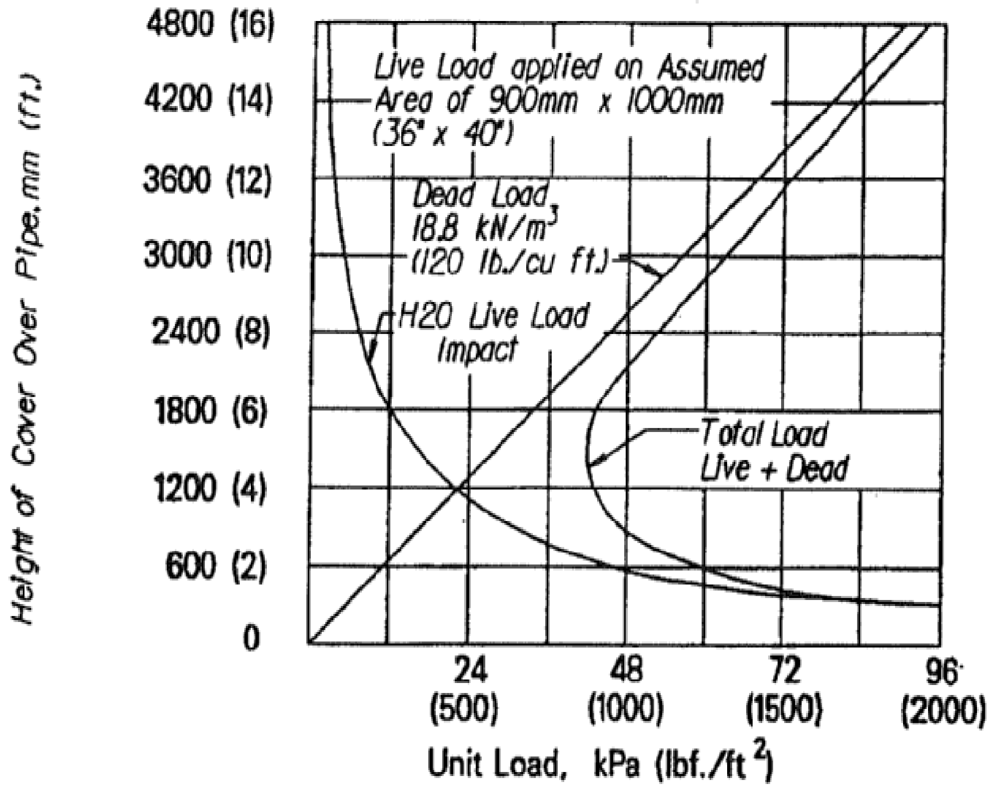
q = *Surcharge load (psf) usually taken as 500 psf*

γ = *Submerged density of soils (pcf) = use 60 pcf*

Source: Peck, R.B. 1969. "Deep Excavations and Tunneling in Soft Ground".

EARTH PRESSURE DIAGRAM	ASSOCIATED TESTING LABAORATORIES, INC. 3143 YELLOWSTONE BLVD., HOUSTON, TEXAS TEL: (713) 748-3717 Fax: (713) 748-3748	
WATER LINE REPLACEMENT IN SHEPHERD FOREST II AREA	WBS NO. S-001000-0047-3	
	PROJECT NO. : G13-225	FIGURE 5c

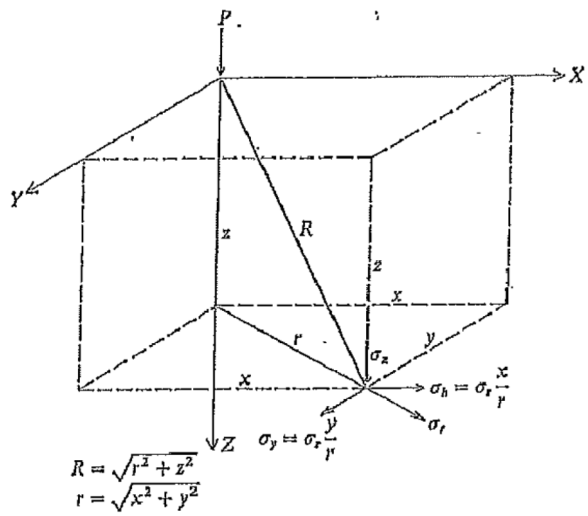
PST 8/28/12



Combined H20 highway live load and dead load is a minimum at about 1500mm (5 ft.) of cover, applied through a pavement 300mm (1 ft.) thick.

HIGHWAY LOADING ON A PIPE UNDER VARIOUS SOIL COVER	ASSOCIATED TESTING LABAORATORIES, INC. 3143 YELLOWSTONE BLVD., HOUSTON, TEXAS TEL: (713) 748-3717 Fax: (713) 748-3748	
SOUTHWEST PUMP STATION IMPROVEMENTS – PACKAGE II	WBS NO. S-001000-0047-3	
	PROJECT NO. : G13-225	FIGURE 6

PST 8/28/12



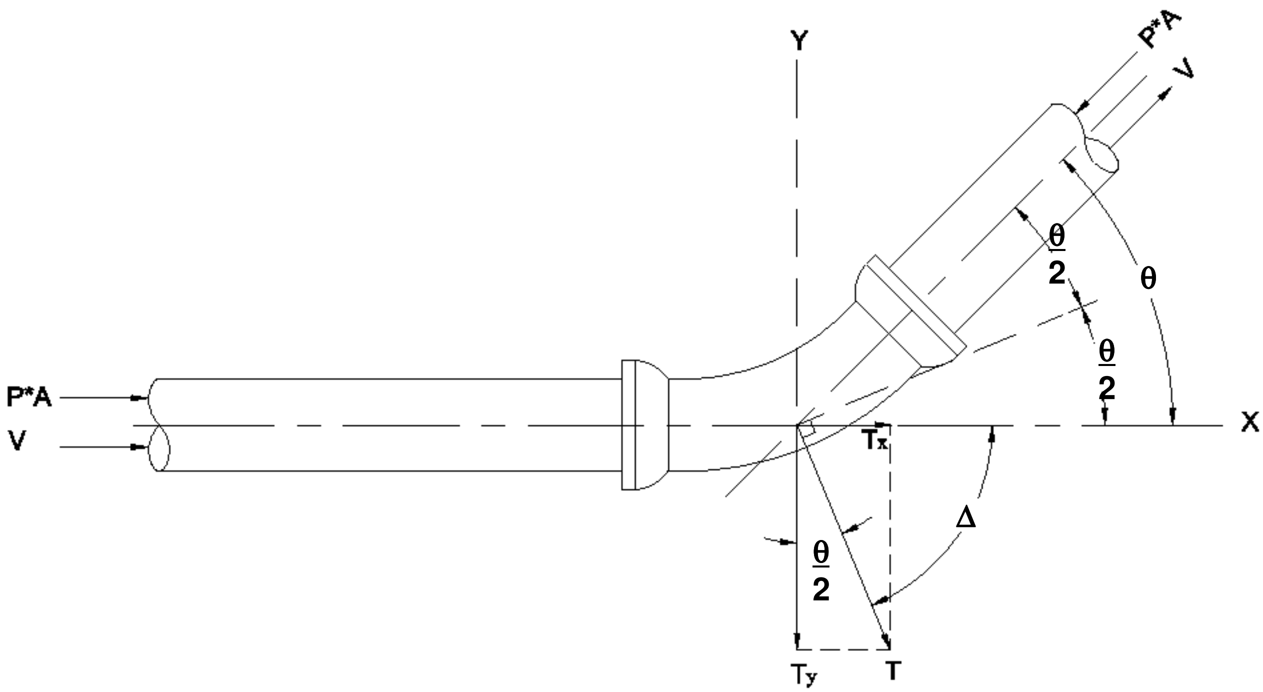
Later Pressure, σ_r:
$\sigma_r = (P/2\pi)\ \{3r^2Z/R^5) - ([1-2\mu]/R[R+z]\}$
For $\mu = 0.5$,
$\sigma_r = P/2\pi\ (2r^2z/R^5)$

Vertical Pressure, σ_z :
$\sigma_z = 3\ P\ z^3 / 2\pi R^5$

P = Point load surcharge
μ = Poisson's ratio if soils, use 0.5
X, y, z = distance in x, y and z direction, respectively

BOUSSINESQ'S EQUATION FOR POINT LOAD SURCHARGE	ASSOCIATED TESTING LABAORATORIES, INC. 3143 YELLOWSTONE BLVD., HOUSTON, TEXAS TEL: (713) 748-3717 Fax: (713) 748-3748	
SOUTHWEST PUMP STATION IMPROVEMENTS – PACKAGE II	WBS NO. S-001000-0047-3	
	PROJECT NO. : G13-225	FIGURE 7

PST 8/28/12



$$T = 2\,P\,A\sin\frac{\theta}{2}$$

$$T_x = P\,A\,(1 - \cos\theta)$$

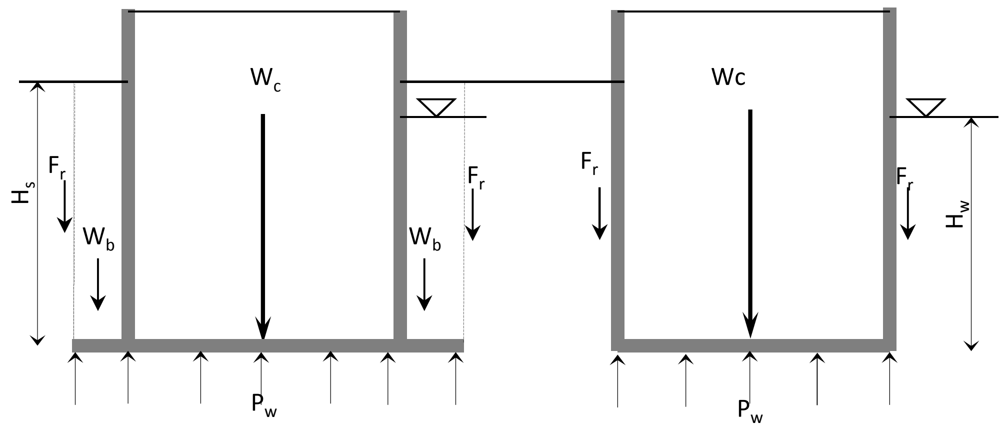
$$T_y = P\,A\sin\theta$$

Where:

T	=	Resultant thrust force, lbs
T_x	=	Resultant thrust force component along x-axis, lbs
T_y	=	Resultant thrust force component along y-axis, lbs
P	=	Maximum sustain pressure of fluid in pipe, psi
A	=	Cross-section area of pipe, square inches
D	=	Inside diameter of pipe, inches
θ	=	Angle of the pipe bend, degrees
Δ	=	Angle between x-axis and resultant force
	=	$\tan^{-1}(T_y/T_x)$, degrees
V	=	Fluid velocity

Source: American Water Works Association, “Concrete Pressure Pipes”, AWWA Manual M9.

THRUST FORCE AT A PIPE BEND	ASSOCIATED TESTING LABAORATORIES, INC. 3143 YELLOWSTONE BLVD., HOUSTON, TEXAS TEL: (713) 748-3717 Fax: (713) 748-3748	
SOUTHWEST PUMP STATION IMPROVEMENTS – PACKAGE II	WBS NO. S-001000-0047-3	
	PROJECT NO. : G13-225	FIGURE 8



Dead Weight of Structure + Dead Weight of Backfill Above Base Extension + Frictional Resistance

$P_w = H_w\gamma_w$
$F_u = A_bP_w$
$W_c/S_{fa}+W_b/S_{fb}+F_r/S_{fc} \geq F_u$
$(S_{fa} = 1.1;\ S_{fb} = 1.5;\ S_{fc} = 3.0)$

Dead Weight of Structure + Frictional Resistance

$P_w = H_w\gamma_w$
$F_u = A_bP_w$
$W_c/S_{fa}+F_r/S_{fc} \geq F_u$
$(S_{fa} = 1.1;\ S_{fc} = 3.0)$

For cohesive soils:
$F_r = \alpha c_nA_n$

For cohesionless soils,
$Fr = p_nK\tan\delta_nA_n$

Where,

H_s	=	Buried depth of wall, ft
H_w	=	Height of water table above base of structure, ft
P_w	=	Total uplift pressure = 62.4 x Hw, psf
F_u	=	Total uplift force exerted on base of structure = Pw x A_b
W_c	=	Dead weight of structure, lbs
W_b	=	Weight of backfill above base of structure, lbs
A_b	=	Area of base, ft^2
F_r	=	Friction resistance developed at the soil/wall interface, lbs
A_n	=	Contact area between the soil/wall interface in layer"n"
c_n	=	Undrained shear strength of cohesive soils at layer "n" at soil/wall interface. See individual boring logs. c_n for the top 8 ft of clays with PI higher than 20 percent should be discounted because of the shrink-swell characteristics of high plasticity clays.
α	=	Adhesion factor, to be multiplied with c_n to obtain the adhesion between the soil/wall interface. Use 0.75 if c_n is less than 0.25 tsf, use 0.67 if c_n is between 0.25 and 0.5 tsf, use 0.5 if c_n is greater than 0.5 tsf but limit the adhesion to 1.5 ksf.
K	=	Coefficient of lateral earth pressure of cohesionless soils. Use 0.4.
p_n	=	Average overburden stress at the mid-depth of cohesionless soil layer "n", psf
δ_n	=	Average frictional angle between cohesionless soil layer "n" and the walls of the structure, use 0.75 of the angle of internal friction (ϕ) of the cohesionless soil. A ϕ of 28 degrees may be used if no specific value is given.
$S_{fa,b,c}$	=	Factors of safety against buoyant uplift force.

BUOYANT UPLIFT RESISTANCE OF A BURIED STRUCTURE	ASSOCIATED TESTING LABAORATORIES, INC. 3143 YELLOWSTONE BLVD., HOUSTON, TEXAS TEL: (713) 748-3717 Fax: (713) 748-3748	
SOUTHWEST PUMP STATION IMPROVEMENTS – PACKAGE II	WBS NO. S-001000-0047-3	
	PROJECT NO. : G13-225	FIGURE 9

LIST OF TABLES

TABLE 1

SUMMARY OF PAVEMENT MEASUREMENTS
PROPOSED SOUTHWEST PUMP STATION IMPROVEMENTS – PACKAGE II
WBS NO. S-001000-0047-3

ATL PROJECT NO. G13-225

Boring Number	Boring Depth (ft)	Piezometer		Asphalt Paving (inch)	Concrete Paving (inch)	Base Material (inch)
		No.	Depth (ft)			
B-1	35	PZ-1	35	--	--	--
B-2	35	--	--	--	--	--
B-3	24	--	--	6	--	6" Crushed gravel
B-4	34	PZ-2	34	--	--	--
B-5	29	--	--	--	--	--

TABLE 2

SUMMARY OF GROUNDWATER MEASUREMENTS
SOUTHWEST PUMP STATION IMPROVEMENTS – PACKAGE II
CITY OF HOUSTON,TEXAS
WBS NO. S-001000-0047-3
ATL PROJECT NO. G13-225

Boring Number	Location	Ground Water in Boreholes			Ground Water in Piezometers		
		During Drilling	After 5 Minutes	At Completion	After 24 Hours	After 7 Days	After 30 Days
B-1 (PZ-1)	Within SWPS	17’	N/A	N/A	(11/07/2013) 14.5’	(11/14/2013) 10.5’	(12/06/2013) 10’
B-2	Feeder Road	33’	28’	N/A	--	--	--
B-3	In Existing Pavement Within Private Property	Dry	Dry	Dry	--	--	--
B-4 (PZ-2)	Richmond Avenue	28’	19’	N/A	(11/05/2013) 17’	(11/14/2013) 12.5’	(12/06/2013) 11’
B-5	Richmond Avenue	27’	N/A	N/A	--	--	--

TABLE 3

ASSOCIATED TESTING LABORATORIES, INC.	PROJECT NAME : SOUTHWEST PUMP STATION IMPROVEMENTS - PACKAGE II
3143 YELLOWSTONE BLVD., HOUSTON, TEXAS 77052	WBS NO: S-001000-0047-3
TEL: (713) 748-3717 FAX: (713) 748-3748	CONSULTANT PROJECT NUMBER: G13-225

BORING NO.	Sample			SPT (blows/ft)	WATER CONTENT (%)	DRY DENSITY (pcf)	Atterberg Limits			PERCENT PASSING SIEVE 200 (%)	UNDRAINED SHEAR STRENGTH (TSF)				TYPE OF MATERIAL
	NO.	DEPTH (ft)	TYPE				LL	PL	PI		UNCONFINED COMPRESSION TEST (TSF)	UU TEST (CONFINING PRESSURE) (TSF)	TORVANE	POCKET PENETRO-METER	
B-1	1	0-2	UD		19		50	19	31	72				2.00	Fat Clay with Sand (CH) fill
(PZ-1)	2	2-4	UD		25	98	66	21	45	87	1.50			4.00	Fat Clay (CH)
	3	4-6	UD		21									3.50	Fat Clay (CH)
	4	6-8	UD		21	108					1.70			4.00	Fat Clay (CH)
	5	8-10	UD		17									4.00	Fat Clay (CH)
	6	10-12	UD		28		75	23	52	88				2.00	Fat Clay (CH)
	7	12-14	UD		29	95					0.50			2.00	Fat Clay (CH)
	8	14-16	UD		13									1.50	Sandy Lean Clay (CL)
	9	16-18	UD		16	116						1.30(0.86)		3.50	Sandy Lean Clay (CL)
	10	18-20	UD		17		28	15	13					2.50	Sandy Lean Clay (CL)
	11	23-25	UD		15									4.50	Sandy Lean Clay (CL)
	12	28-30	SS	14	23					16					Silty Sand (SM)
	13	33-35	SS	85	19										Silty Sand (SM)
B-2	1	0-2	UD		21									3.00	Fat Clay with Sand (CH)
	2	2-4	UD		19		50	19	31	82				3.25	Fat Clay with Sand (CH)
	3	4-6	UD		20	107					1.05			3.50	Fat Clay with Sand (CH)
	4	6-8	UD		16									4.50	Fat Clay with Sand (CH)
	5	8-10	UD		18		68	22	46	85				4.50	Fat Clay with Sand (CH)
	6	10-12	UD		20									4.50	Fat Clay with Sand (CH)
	7	12-14	UD		21	108					0.90			2.50	Fat Clay with Sand (CH)
	8	14-16	UD		26									3.00	Fat Clay with Sand (CH)
	9	16-18	UD		17		44	18	26	69				3.25	Sandy Lean Clay (CL)
	10	18-20	UD		18	114					0.90			2.50	Sandy Lean Clay (CL)
	11	23-25	UD		14	119						2.77(1.15)		3.75	Sandy Lean Clay (CL)
	12	28-30	UD		16		30	16	14	53				3.25	Sandy Lean Clay (CL)
	13	33-35	SS	20	20					27					Silty Sand (SM)

Legend:
UD - Undisturbed Sample Extruded in Field
UL - Undisturbed Sample Extruded in Lab
Designates consolidation test Performed
AG - Auger Cutting in Field
SS - Split Spoon Sample
SPT - Standard Penetration Test

TABLE 3 (cont'd)

ASSOCIATED TESTING LABORATORIES, INC.	PROJECT NAME : SOUTHWEST PUMP STATION IMPROVEMENTS - PACKAGE II
3143 YELLOWSTONE BLVD., HOUSTON, TEXAS 77052	WBS NO: S-001000-0047-3
TEL: (713) 748-3717 FAX: (713) 748-3748	CONSULTANT PROJECT NUMBER: G13-225

BORING NO.	Sample			SPT (blows/ft)	WATER CONTENT (%)	DRY DENSITY (pcf)	Atterberg Limits			PERCENT PASSING SIEVE 200 (%)	UNDRAINED SHEAR STRENGTH (TSF)				TYPE OF MATERIAL
	NO.	DEPTH (ft)	TYPE				LL	PL	PI		UNCONFINED COMPRESSION TEST (TSF)	UU TEST (CONFINING PRESSURE) (TSF)	TORVANE	POCKET PENETRO-METER	
B-3	1	0-2	AU		26										Fat Clay (CH)
	2	2-4	UD		22		68	22	46	88				3.00	Fat Clay (CH)
	3	4-6	UD		23									2.75	Fat Clay (CH)
	4	6-8	UD		22	102					0.95			2.50	Fat Clay (CH)
	5	8-10	UD		24		69	22	47	90				3.00	Fat Clay (CH)
	6	10-12	UD		24									2.75	Fat Clay (CH)
	7	12-14	UD		25	101					1.10			3.50	Fat Clay (CH)
	8	14-16	UD		25		79	23	56	88				2.00	Fat Clay (CH)
	9	16-18	UD		20									1.75	Sandy Lean Clay (CL)
	10	18-20	UD		19	109						0.79(0.94)		1.50	Sandy Lean Clay (CL)
	10	20-22	UD		14		40	17	23	70				4.00	Sandy Lean Clay (CL)
	11	22-24	UD		14	122					0.75			2.00	Sandy Lean Clay (CL)
B-4	1	0-2	UD		19		47	18	29	81				1.00	Lean Clay with Sand (CL)
(PZ-2)	2	2-4	UD		22	104					0.95			2.50	Lean Clay with Sand (CL)
	3	4-6	UD		13									4.50	Lean Clay with Sand (CL)
	4	6-8	UD		15		60	20	40	85				4.50	Fat Clay with Sand (CH)
	5	8-10	UD		27									3.25	Fat Clay with Sand (CH)
	6	10-12	UD		18									3.50	Fat Clay with Sand (CH)
	7	12-14	UD		19	108					0.70			2.00	Fat Clay with Sand (CH)
	8	14-16	UD		17		36	17	19					1.75	Sandy Lean Clay (CL)
	9	16-18	UD		19	111						1.19(0.86)		3.25	Sandy Lean Clay (CL)
	10	18-20	UD		18	113					1.00			3.50	Sandy Lean Clay (CL)
	11	23-25	UD		13		30	16	14	55				3.25	Sandy Lean Clay (CL)
	12	28-20	SS	10	22					15					Silty Sand (SM)
	13	33-34	SS	12	21										Silty Sand (SM)

Legend:

UD - Undisturbed Sample Extruded in Field
UL - Undisturbed Sample Extruded in Lab
Designates consolidation test Performed

AG - Auger Cutting in Field
SS - Split Spoon Sample
SPT - Standard Penetration Test

TABLE 3 (cont'd)

ASSOCIATED TESTING LABORATORIES, INC.	PROJECT NAME : SOUTHWEST PUMP STATION IMPROVEMENTS - PACKAGE II
3143 YELLOWSTONE BLVD., HOUSTON, TEXAS 77052	WBS NO: S-001000-0047-3
TEL: (713) 748-3717 FAX: (713) 748-3748	CONSULTANT PROJECT NUMBER: G13-225

BORING NO.	Sample			SPT (blows/ft)	WATER CONTENT (%)	DRY DENSITY (pcf)	Atterberg Limits			PERCENT PASSING SIEVE 200 (%)	UNDRAINED SHEAR STRENGTH (TSF)				TYPE OF MATERIAL
	NO.	DEPTH (ft)	TYPE				LL	PL	PI		UNCONFINED COMPRESSION TEST (TSF)	UU TEST (CONFINING PRESSURE) (TSF)	TORVANE	POCKET PENETRO-METER	
B-5	1	0-2	UD		13									3.25	Lean Clay with Sand(CL) fill
	2	2-4	UD		19		61	21	40	78				3.50	Fat Clay with Sand (CH)
	3	4-6	UD		21	105					0.80			2.00	Fat Clay with Sand (CH)
	4	6-8	UD		23									3.00	Fat Clay with Sand (CH)
	5	8-10	UD		31									2.00	Fat Clay with Sand (CH)
	6	10-12	UD		26		54	19	35	80				1.00	Fat Clay with Sand (CH)
	7	12-14	UD		19									2.00	Fat Clay with Sand (CH)
	8	14-16	UD		19	111					1.05			3.50	Fat Clay with Sand (CH)
	9	16-18	UD		18		48	18	30	70				3.25	Sandy Lean Clay (CL)
	10	18-20	UD		13	122					1.85			4.00	Sandy Lean Clay (CL)
	11	23-25	UD		15	118	40	17	23		2.05			4.50	Sandy Lean Clay (CL)
	12	27-29	SS	12	21					30					Silty Sand (SM)

Legend:

UD - Undisturbed Sample Extruded in Field
UL - Undisturbed Sample Extruded in Lab
Designates consolidation test Performed

AG - Auger Cutting in Field
SS - Split Spoon Sample
SPT - Standard Penetration Test

TABLE 4.1

Marston Soil Coefficients (C_d) for Trench Conduits

A = $K\mu'$ = • 1924 Granular materials without cohesion
B = $K\mu'$ = • 165 Maximum for sand and gravel
C = $K\mu'$ = • 150 Maximum for saturated top soil
D = $K\mu'$ = • 130 Ordinary maximum for clay
E = $K\mu'$ = • 110 Maximum for saturated clay

H/B_d	A	B	C	D	E
0.05	0.050	0.050	0.050	0.050	0.050
0.10	0.098	0.098	0.099	0.099	0.099
0.15	0.146	0.146	0.147	0.147	0.148
0.20	0.192	0.194	0.194	0.195	0.196
0.25	0.238	0.240	0.241	0.242	0.243
0.30	0.283	0.286	0.287	0.289	0.290
0.35	0.327	0.331	0.332	0.335	0.337
0.40	0.371	0.375	0.377	0.380	0.383
0.45	0.413	0.418	0.421	0.425	0.428
0.50	0.455	0.461	0.464	0.469	0.473
0.55	0.496	0.503	0.507	0.512	0.518
0.60	0.536	0.544	0.549	0.555	0.562
0.65	0.575	0.585	0.591	0.598	0.606
0.70	0.614	0.625	0.631	0.640	0.649
0.75	0.651	0.664	0.672	0.681	0.691
0.80	0.689	0.703	0.711	0.722	0.734
0.85	0.725	0.741	0.750	0.763	0.775
0.90	0.761	0.779	0.789	0.802	0.817
0.95	0.796	0.816	0.827	0.842	0.857

H/B_d	A	B	C	D	E
3.00	1.780	1.904	1.978	2.083	2.196
3.10	1.810	1.941	2.018	2.128	2.247
3.20	1.840	1.976	2.057	2.172	2.297
3.30	1.869	2.010	2.095	2.215	2.346
3.40	1.896	2.044	2.131	2.257	2.394
3.50	1.923	2.076	2.167	2.298	2.441
3.60	1.948	2.107	2.201	2.338	2.487
3.70	1.973	2.137	2.235	2.376	2.531
3.80	1.997	2.166	2.267	2.414	2.575
3.90	2.019	2.194	2.299	2.451	2.618
4.00	2.041	2.221	2.329	2.487	2.660
4.10	2.062	2.247	2.359	2.522	2.701
4.20	2.082	2.273	2.388	2.556	2.741
4.30	2.102	2.297	2.416	2.589	2.780
4.40	2.121	2.321	2.443	2.621	2.819
4.50	2.139	2.344	2.469	2.652	2.856
4.60	2.156	2.366	2.495	2.683	2.893
4.70	2.173	2.388	2.520	2.713	2.929
4.80	2.189	2.409	2.543	2.742	2.964

CONCRETE PRESSURE PIPE

Source: American Water Works Association, Manual of Water Supply Practices, "Concrete Pressure Pipe, AMMA M9

MARSTON SOIL COEFFICIENTS (C_d) FOR TRENCH CONDUITS	ASSOCIATED TESTING LABAORATORIES, INC. 3143 YELLOWSTONE BLVD., HOUSTON, TEXAS TEL: (713) 748-3717 Fax: (713) 748-3748
SOUTHWEST PUMP STATION IMPROVEMENTS – PACKAGE II	WBS NO. S-001000-0047-3 PROJECT NO. : G13-225 — TABLE 4 (1 of 2)

PST 8/28/12

TABLE 4.1 *(cont)*

H/B_d	A	B	C	D	E
1.00	0.830	0.852	0.864	0.881	0.898
1.05	0.864	0.887	0.901	0.919	0.938
1.10	0.897	0.922	0.937	0.957	0.977
1.15	0.929	0.957	0.973	0.994	1.016
1.20	0.961	0.991	1.008	1.031	1.055
1.25	0.992	1.024	1.042	1.067	1.093
1.30	1.023	1.057	1.076	1.103	1.131
1.35	1.053	1.089	1.110	1.139	1.168
1.40	1.082	1.121	1.143	1.173	1.205
1.45	1.111	1.152	1.176	1.208	1.241
1.50	1.140	1.183	1.208	1.242	1.278
1.55	1.167	1.213	1.240	1.276	1.313
1.60	1.195	1.243	1.271	1.309	1.349
1.65	1.221	1.272	1.301	1.342	1.384
1.70	1.248	1.301	1.332	1.374	1.418
1.75	1.273	1.329	1.361	1.406	1.452
1.80	1.299	1.357	1.391	1.437	1.486
1.85	1.323	1.385	1.420	1.469	1.520
1.90	1.348	1.412	1.448	1.499	1.553
1.95	1.372	1.438	1.476	1.530	1.586
2.00	1.395	1.464	1.504	1.560	1.618
2.10	1.440	1.515	1.558	1.618	1.682
2.20	1.484	1.564	1.610	1.675	1.744
2.30	1.526	1.612	1.661	1.731	1.805
2.40	1.567	1.658	1.711	1.785	1.865
2.50	1.606	1.702	1.759	1.838	1.923
2.60	1.643	1.745	1.805	1.890	1.980
2.70	1.679	1.787	1.850	1.940	2.036
2.80	1.714	1.827	1.894	1.989	2.090
2.90	1.747	1.867	1.937	2.037	2.144

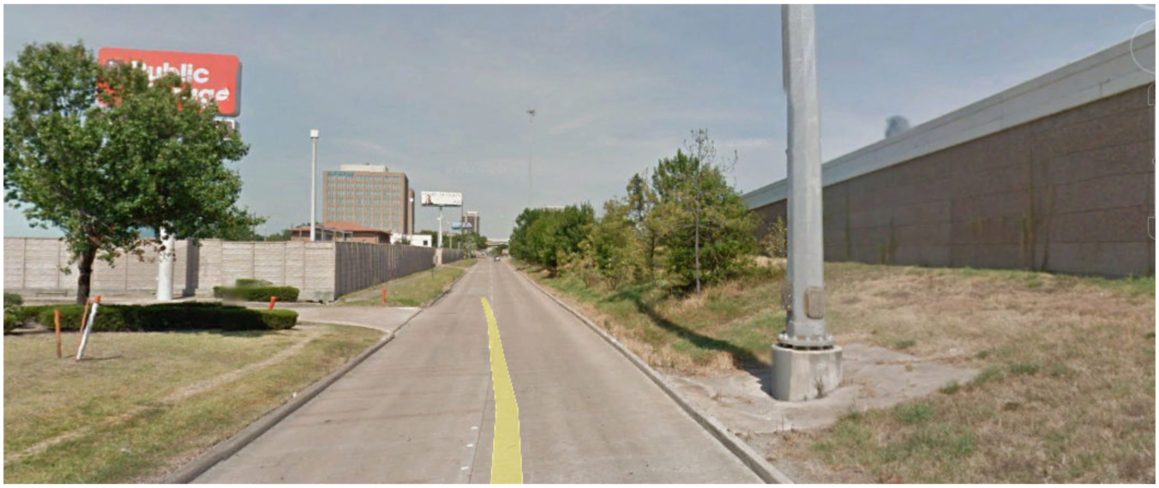
H/B_d	A	B	C	D	E
4.90	2.204	2.429	2.567	2.770	2.999
5.00	2.219	2.448	2.590	2.798	3.032
5.10	2.234	2.467	2.612	2.825	3.065
5.20	2.247	2.486	2.633	2.851	3.098
5.30	2.261	2.503	2.654	2.877	3.129
5.40	2.273	2.520	2.674	2.901	3.160
5.50	2.286	2.537	2.693	2.926	3.190
5.60	2.298	2.553	2.712	2.949	3.220
5.70	2.309	2.568	2.730	2.972	3.248
5.80	2.320	2.583	2.748	2.995	3.277
5.90	2.330	2.598	2.766	3.017	3.304
6.00	2.340	2.612	2.782	3.038	3.331
6.20	2.360	2.639	2.814	3.079	3.383
6.40	2.377	2.664	2.845	3.118	3.433
6.60	2.394	2.687	2.873	3.155	3.481
6.80	2.409	2.709	2.900	3.190	3.527
7.00	2.423	2.730	2.925	3.223	3.571
7.20	2.436	2.749	2.949	3.255	3.613
7.40	2.448	2.767	2.971	3.285	3.653
7.60	2.459	2.784	2.992	3.313	3.691
7.80	2.470	2.799	3.012	3.340	3.728
8.00	2.479	2.814	3.031	3.366	3.763
8.50	2.500	2.847	3.073	3.424	3.845
9.00	2.517	2.875	3.109	3.476	3.918
9.50	2.532	2.898	3.141	3.521	3.983
10.0	2.543	2.919	3.167	3.560	4.042
15.0	2.591	3.009	3.296	3.768	4.378
20.0	2.598	3.026	3.325	3.825	4.490
30.0	2.599	3.030	3.333	3.845	4.539
40.0	2.599	3.030	3.333	3.846	4.545

EXTERNAL LOADING

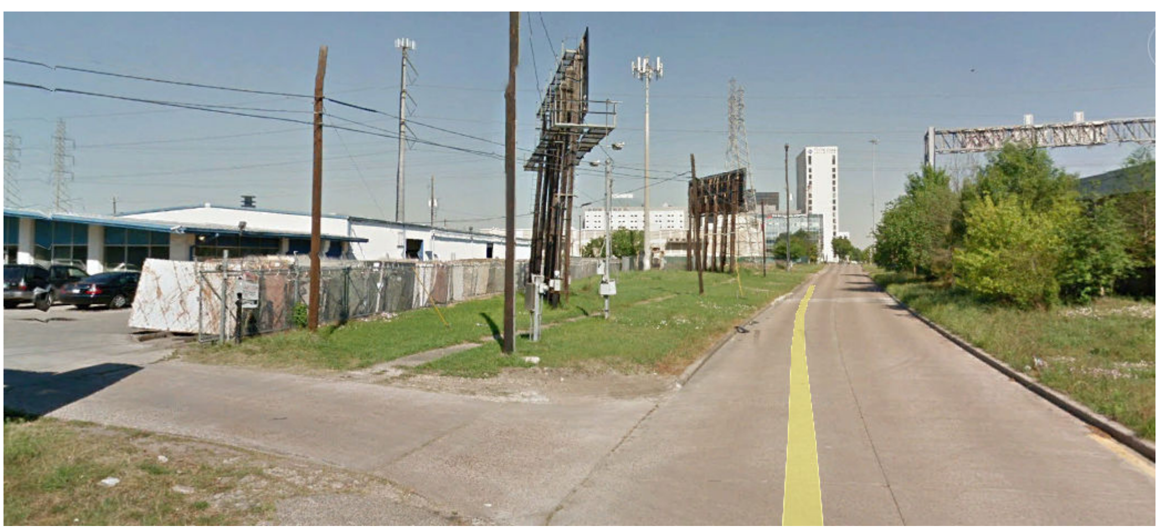
APPENDIX 1

PHOTOGRAPHS OF THE PROJECT SITE

PHOTOGRAPHS OF THE PROJECT SITE
SWPS IMPROVEMENTS – PACKAGE II
WBS NO. S-001000-0047-3
ATL PROJECT NO. G13-225



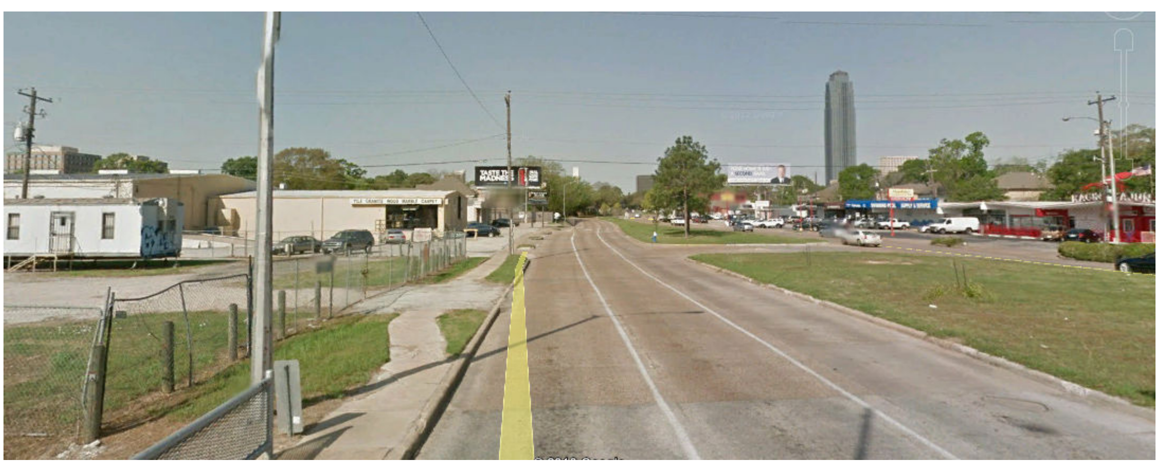
Looking W. along US 59 EB Feeder, at NE corner of Southwest Pump Station



Looking E. along US 59 WB Feeder, from entrance roadway to Holmes Family Properties, LTD. facility

PHOTOGRAPHS OF THE PROJECT SITE
SWPS IMPROVEMENTS – PACKAGE II
WBS NO. S-001000-0047-3
ATL PROJECT NO. G13-225

Looking W from intersection of WB US 59 Feeder and HL&P easement



Looking W along EB Richmond Ave, from NE corner of Holmes Family Properties, LTD. facility

APPENDIX 2

PIEZOMETER INSTALLATION REPORTS

PIEZOMETER INSTALLATION REPORT

PROJECT NAME: PROPOSED SOUTHWEST PUMP STATION IMPROVEMENTS–PACKAGE II WBS No.: S–001000–0047–3		PIEZOMETER NO.: B–1 (PZ–1)
GEOTECHNICAL CONSULTANT ASSOCIATED TESTING LABORATORIES, INC.	DESIGN CONSULTANT ISANI CONSULTANTS, L.P.	CITY OF HOUSTON

COMPLETION DATE: 11–6–13

DRY AUGERED 0 TO 35 FT

WASH BORED ______ TO ______ FT

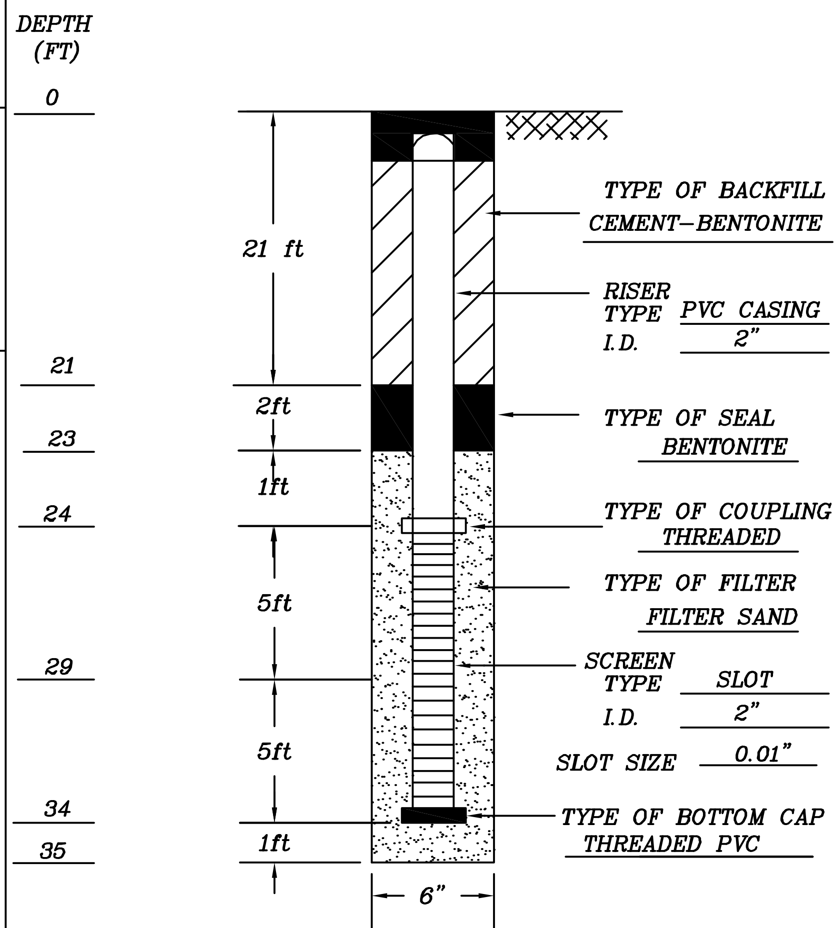
DRILING FLUID: ______

DEVELOPMENT DATE: 11–6–13

METHOD OF DEVELOPMENT: BAILING

WATER LEVEL READING:

DATE	READING
11–7–13	14.5'
11–14–13	10.5'
12–6–13	10'



(NOT TO SCALE)

REMARKS:

NOTES:

DRILLED BY; Soltek,LLC	STARTED: 11–6–13	ATL job No. G13–225
LOGGED BY: PV	COMPLETED: 11–6–13	
CHECKED BY: JITU	APPROVED BY: PST	SHEET 1 OF 2

ASSOCIATED TESTING LABORATORIES, INC.

PIEZOMETER INSTALLATION REPORT

PROJECT NAME: PROPOSED SOUTHWEST PUMP STATION IMPROVEMENTS–PACKAGE II WBS No.: S–001000–0047–3	PIEZOMETER NO.: B–4 (PZ–2)

GEOTECHNICAL CONSULTANT	DESIGN CONSULTANT	
ASSOCIATED TESTING LABORATORIES, INC.	ISANI CONSULTANTS, L.P.	CITY OF HOUSTON

COMPLETION DATE: 11–4–13

DRY AUGERED 0 TO 34 FT

WASH BORED ______ TO ______ FT

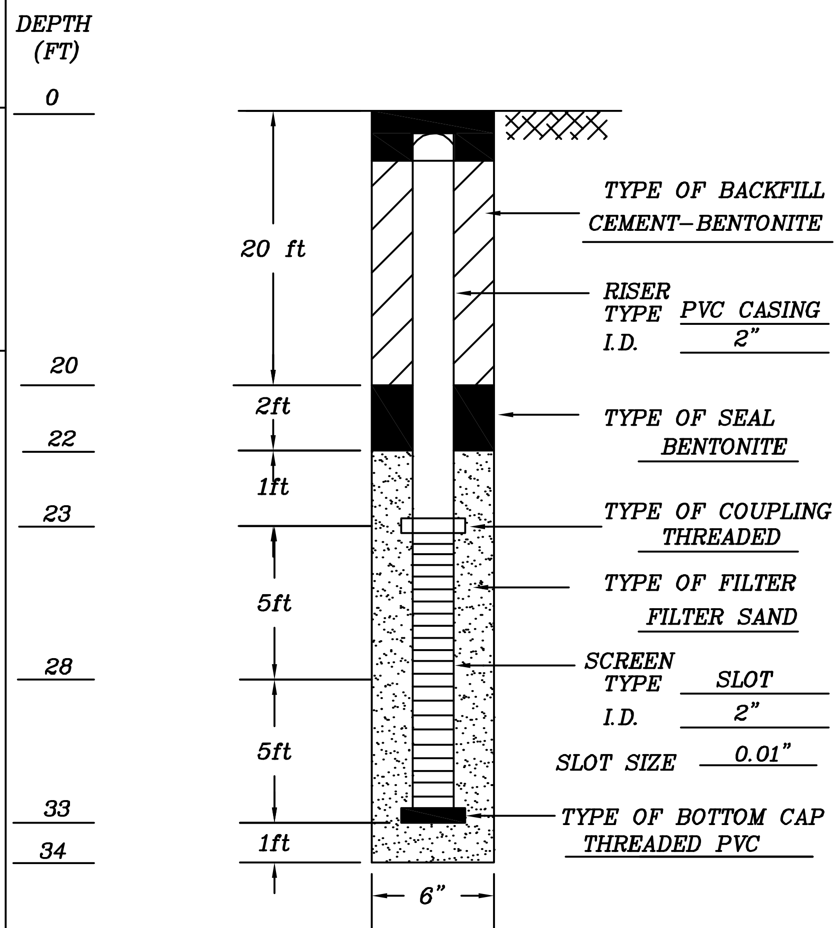
DRILING FLUID: ____________

DEVELOPMENT DATE: 11–4–13

METHOD OF DEVELOPMENT: BAILING

WATER LEVEL READING:

DATE	READING
11–5–13	17'
11–14–13	12.5'
12–6–13	11'



(NOT TO SCALE)

REMARKS:

NOTES:

DRILLED BY;	STARTED:	
Soltek,LLC	11–4–13	ATL job No. G13–225
LOGGED BY: PV	COMPLETED: 11–4–13	
CHECKED BY: JITU	APPROVED BY: PST	SHEET 2 OF 2

ASSOCIATED TESTING LABORATORIES, INC.

G13-225

STATE OF TEXAS WELL REPORT for Tracking #348260

Owner:	**City of Houston Geo Dept.**	Owner Well #:	**B-1**
Address:	**611 Walker Houston , TX 77002**	Grid #:	**65-21-2**
Well Location:	**4410 Southwest Freeway Houston , TX 77027**	Latitude:	**29° 43' 28" N**
Well County:	**Harris**	Longitude:	**095° 26' 35" W**
Elevation:	**No Data**	GPS Brand Used:	**Magellan**
Type of Work:	**New Well**	Proposed Use:	**Monitor**

Drilling Date:	Started: **11/6/2013** Completed: **11/6/2013**
Diameter of Hole:	Diameter: **4 in From Surface To 35 ft**
Drilling Method:	Other:
Borehole Completion:	Gravel Packed From: **23 ft to 35 ft** Gravel Pack Size: **20/40**
Annular Seal Data:	1st Interval: **From 0 ft to 23 ft with 1 bentonite (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **No Data** Cemented By: **No Data** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**
Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**20/40 23 - 35**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**No Data**
Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Envirotech Drilling Services 2718 South Brompton Drive Pearland , TX 77584**
Driller License Number:	**58171**

Licensed Well Driller Signature:	**Jaime Vasquez**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking **#348260**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-6 Dark gray clay
6-14 Light gray/tan clay
14-28 Light gray sandy clay
28-35 Tan sand

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
2 New PVC Riser 0-25 Sch. 40
2 New PVC Screen 25-35 0.010

G13-225

STATE OF TEXAS WELL REPORT for Tracking #348261

Owner:	**City of Houston Geo Dept.**	Owner Well #:	**B-4**
Address:	**611 Walker Houston , TX 77002**	Grid #:	**65-21-2**
Well Location:	**Richmond Ave. meian Houston , TX**	Latitude:	**29° 43' 34" N**
Well County:	**Harris**	Longitude:	**095° 26' 33" W**
Elevation:	**No Data**	GPS Brand Used:	**Magellan**
Type of Work:	**New Well**	Proposed Use:	**Monitor**

Drilling Date:	Started: **11/4/2013** Completed: **11/4/2013**
Diameter of Hole:	Diameter: **4 in From Surface To 34 ft**
Drilling Method:	**Mud Rotary**
Borehole Completion:	Gravel Packed From: **22 ft to 34 ft** Gravel Pack Size: **20/40**
Annular Seal Data:	1st Interval: **From 0 ft to 22 ft with 1 bentonite (#sacks and material)** 2nd Interval: **No Data** 3rd Interval: **No Data** Method Used: **No Data** Cemented By: **No Data** Distance to Septic Field or other Concentrated Contamination: **No Data** Distance to Property Line: **No Data** Method of Verification: **No Data** Approved by Variance: **No Data**
Surface Completion:	**Surface Sleeve Installed**

Water Level:	Static level: **No Data** Artesian flow: **No Data**
Packers:	**20/40 22 - 34**
Plugging Info:	Casing or Cement/Bentonite left in well: **No Data**
Type Of Pump:	**No Data**
Well Tests:	**No Data**

Water Quality:	Type of Water: **No Data** Depth of Strata: **No Data** Chemical Analysis Made: **No** Did the driller knowingly penetrate any strata which contained undesirable constituents: **No**
Certification Data:	The driller certified that the driller drilled this well (or the well was drilled under the driller's direct supervision) and that each and all of the statements herein are true and correct. The driller understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Envirotech Drilling Services 2718 South Brompton Drive Pearland , TX 77584**
Driller License Number:	**58171**

Licensed Well Driller Signature:	**Jaime Vasquez**
Registered Driller Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Comments:	**No Data**

IMPORTANT NOTICE FOR PERSONS HAVING WELLS DRILLED CONCERNING CONFIDENTIALITY

TEX. OCC. CODE Title 12, Chapter 1901.251, authorizes the owner (owner or the person for whom the well was drilled) to keep information in Well Reports confidential. The Department shall hold the contents of the well log confidential and not a matter of public record if it receives, by certified mail, a written request to do so from the owner.

Please include the report's Tracking number (Tracking **#348261**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

DESC. & COLOR OF FORMATION MATERIAL

From (ft) To (ft) Description
0-8 Dark gray sandy clay
8-28 Tan/gray sandy clay
28-34 Tan sand

CASING, BLANK PIPE & WELL SCREEN DATA

Dia. New/Used Type Setting From/To
2 New PVC Riser 0-24 Sch. 40
2 New PVC Screen 24-34 0.010

G13-225

STATE OF TEXAS PLUGGING REPORT for Tracking #92051

Owner:	**City Of Houston Geo Dept**	Owner Well #:	**B1**
Address:	**611 Walker Houston , TX 77002**	Grid #:	**65-21-2**
Well Location:	**4410 Southwest Freeway Houston , TX 77027**	Latitude:	**29° 43' 28" N**
Well County:	**Harris**	Longitude:	**095° 26' 35" W**
		GPS Brand Used:	**Magellan**

Well Type: **Monitor**

HISTORICAL DATA ON WELL TO BE PLUGGED

Original Well Driller:	**No Data**
Driller's License Number of Original Well Driller:	**No Data**
Date Well Drilled:	**11/6/2013**
Well Report Tracking Number:	**No Data**
Diameter of Borehole:	**2 inches**
Total Depth of Borehole:	**35' feet**

Date Well Plugged:	**12/21/2013**
Person Actually Performing Plugging Operation:	**Jaime Vasquez**
License Number of Plugging Operator:	**58171**
Plugging Method:	**Pour in 3/8 bentonite chips when standing water in well is less than 100 feet in depth, cement top 2 feet.**
Plugging Variance #:	**No Data**
Casing Left Data:	1st Interval: **2 inches diameter, From .5 ft to 35 ft** 2nd Interval: **No Data** 3rd Interval: **No Data**
Cement/Bentonite	1st Interval: **From 0 ft to 35 ft; Sack(s)/type of cement used: 2.5**

Plugs Placed in Well:	2nd Interval: **No Data** 3rd Interval: **No Data** 4th Interval: **No Data** 5th Interval: **No Data**

Certification Data:	The plug installer certified that the plug installer plugged this well (or the well was plugged under the plug installer's direct supervision) and that each and all of the statements herein are true and correct. The plug installer understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Envirotech Drilling Services** **2718 South Brompton Drive** **Pearland , TX 77584**
Plug Installer License Number:	**58171**
Licensed Plug Installer Signature:	**Jaime Vasquez**
Registered Plug Installer Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Plugging Method Comments:	**Graduted well in place**

Please include the plugging report's tracking number (Tracking #**92051**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

STATE OF TEXAS PLUGGING REPORT for Tracking #92052

Owner:	**City Of Houston Geo Dept**	Owner Well #:	**B4**
Address:	**611 Walker** **Houston , TX 77002**	Grid #:	**65-21-2**
Well Location:	**Richmond Ave. Median** **Houston , TX 77027**	Latitude:	**29° 43' 34" N**
Well County:	**Harris**	Longitude:	**095° 26' 33" W**
		GPS Brand Used:	**Magellan**

Well Type: **Monitor**

HISTORICAL DATA ON WELL TO BE PLUGGED

Original Well Driller:	**No Data**
Driller's License Number of Original Well Driller:	**No Data**
Date Well Drilled:	**11/6/2013**
Well Report Tracking Number:	**No Data**
Diameter of Borehole:	**2 inches**
Total Depth of Borehole:	**34' feet**

Date Well Plugged:	**12/21/2013**
Person Actually Performing Plugging Operation:	**Jaime Vasquez**
License Number of Plugging Operator:	**58171**
Plugging Method:	**Pour in 3/8 bentonite chips when standing water in well is less than 100 feet in depth, cement top 2 feet.**
Plugging Variance #:	**No Data**
Casing Left Data:	1st Interval: **2 inches diameter, From .5 ft to 34 ft** 2nd Interval: **No Data** 3rd Interval: **No Data**
Cement/Bentonite	1st Interval: **From 0 ft to 34 ft; Sack(s)/type of cement used: 2.5**

Plugs Placed in Well:	2nd Interval: **No Data** 3rd Interval: **No Data** 4th Interval: **No Data** 5th Interval: **No Data**

Certification Data:	The plug installer certified that the plug installer plugged this well (or the well was plugged under the plug installer's direct supervision) and that each and all of the statements herein are true and correct. The plug installer understood that failure to complete the required items will result in the log(s) being returned for completion and resubmittal.
Company Information:	**Envirotech Drilling Services** **2718 South Brompton Drive** **Pearland , TX 77584**
Plug Installer License Number:	**58171**
Licensed Plug Installer Signature:	**Jaime Vasquez**
Registered Plug Installer Apprentice Signature:	**No Data**
Apprentice Registration Number:	**No Data**
Plugging Method Comments:	**Graduted well in place**

Please include the plugging report's tracking number (Tracking #**92052**) on your written request.

Texas Department of Licensing & Regulation
P.O. Box 12157
Austin, TX 78711
(512) 463-7880

APPENDIX 3

BORING LOGS AND KEY TO LOG TERMS AND SYMBOLS

Associated Testing Laboratories, Inc.
3143 Yellowstone Blvd
Houston, Texas-77054

LOG OF BORING B-1 (PZ-1)

PROJECT: Proposed Southwest Pump Station Improvements-Package II
WBS No. S-001000-0047-3

PROJECT NO.: G13-225

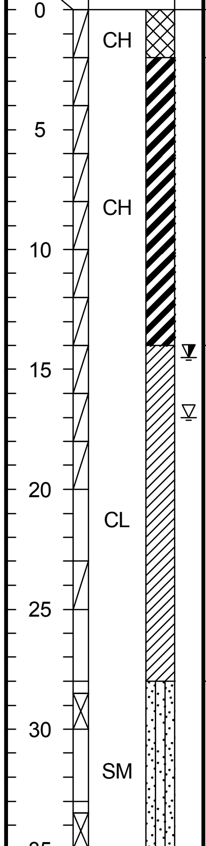
BORING TYPE: Auger

DATE: 11-6-13

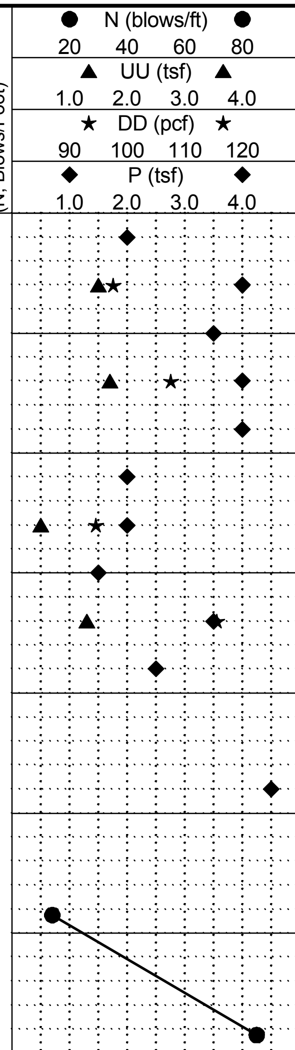
SURFACE ELEVATION: 55.73

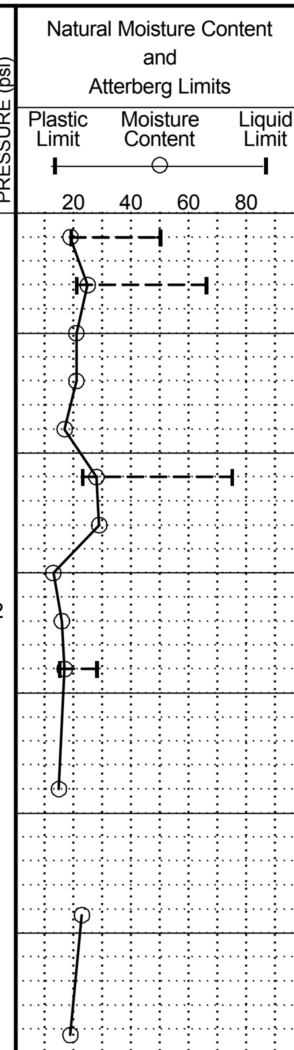
LOCATION

Within SWPS
Northing: 13829865.98
Easting: 3095147.98



DEPTH (ft.)	USC	MATERIAL DESCRIPTION	POCKET PENETROMETER (P, tsf)	BLOW COUNT (N, Blows/Foot)	DRY DENSITY (pcf)	UNDRAINED SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	CH	Fill: Fat Clay With Sand (CH), stiff, high plasticity, light gray & tan with shells	2.0						19	50	19	31	72	
			4.0		98	1.5		0	25	66	21	45	87	
5	CH	Fat Clay With Sand (CH), very stiff, high plasticity, light gray & tan	3.5						21					
		.. very stiff, light gray & tan below 4'	4.0		108	1.7		0	21					
		.. with ferrous nodules below 6'												
		.. with calcareous nodules below 8'	4.0						17					
10		.. stiff below 10'	2.0						28	75	23	52	88	
			2.0		95	0.5		0	29					
15	CL	Sandy Lean Clay (CL), stiff, medium plasticity, light gray & tan	1.5						13					
			3.5		116	1.30		12	16					
			2.5						17	28	15	13		
20														
			4.5						15					
25														
30	SM	Silty Sand (SM), medium dense, non plastic, light gray & tan (wet)		14					23				16	
35		.. very dense, reddish brown below 33'		85					19					





Water Level Intial: ▽ After Drilling: ▼ 24 Hrs: ▼
Water Observations: Initial Water Level: 17', After Drilling: N/A.

Sample Key: ☒ SPT ◫ Shelby Tube ▤ Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
Q_u - Unconfined Comp. Strength (tsf)
DD - Dry Density (pcf)

Notes:
Augered dry to 35' ; PZ water level: 14.5' (11-7-2013); PZ water level: 10.5' (11-14-2013); PZ water level: 10' (12-6-2013); Drilled By: Soltek, LLC, Logged BY: PV, Checked By: Jitu/pankaj QC/QA By: PST

Associated Testing Laboratories, Inc.
3143 Yellowstone Blvd
Houston, Texas-77054

LOG OF BORING B-2

PROJECT: Proposed Southwest Pump Station Improvements-Package II
WBS No. S-001000-0047-3

PROJECT NO.: G13-225 BORING TYPE: Auger

DATE: 11-5-13

SURFACE ELEVATION: 55.63

LOCATION

Feeder Road
Northing: 13830302.18
Easting: 3095122.52

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	WATER LEVEL	MATERIAL DESCRIPTION	POCKET PENETROMETER (P, tsf)	BLOW COUNT (N, Blows/Foot)	DRY DENSITY (pcf)	UNDRAINED SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	LIQUID LIMIT LL	PLASTIC LIMIT PL	PLASTICITY INDEX PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	CH		Fat Clay With Sand (CH), very stiff, high plasticity, dark gray	3.0						21					
				3.25						19	50	19	31	82	
5			.. light gray & tan below 4'	3.5		107	1.05		0	20					
			.. hard, with calcareous nodules below 6'	4.5						16					
			.. with ferrous nodules below 8'	4.5						18	68	22	46	85	
10				4.5						20					
			.. stiff below 10'	2.5		108	0.9		0	21					
15				3.0						26					
	CL		Sandy Lean Clay (CL), very stiff, high plasticity, light gray & tan	3.25						17	44	18	26	69	
20			.. stiff, with sand seams below 18'	2.5		114	0.9		0	18					
25			.. very stiff below 23'	3.75		119	2.77		16	14					
30		▼ (28')		3.25						16	30	16	14	53	
35	SM	▽ (33')	Silty Sand (SM), medium dense, non plastic, light gray & tan		20					20				27	

Water Level Initial: ▽ After Drilling: ▼ 24 Hrs: ▼

Water Observations: Initial Water Level: 33', After 5 minutes: 28'

Sample Key: SPT, Shelby Tube, Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
Q_u - Unconfined Comp. Strength (tsf)
DD - Dry Density (pcf)

Notes:
Augered dry to 35' & Hole Grouted after Drilling. Drilled By: Soltek, LLC, Logged BY: PV, Checked By: Jitu/pankaj, QC/QA By: PST

Associated Testing Laboratories, Inc.
3143 Yellowstone Blvd
Houston, Texas-77054

LOG OF BORING B-3

DATE: 11-4-13

SURFACE ELEVATION: 56.35

PROJECT: Proposed Southwest Pump Station Improvements-Package II
WBS No. S-001000-0047-3

PROJECT NO.: G13-225 BORING TYPE: Auger

LOCATION

In Existing Pavement Within Private Property
Northing: 13830478.75
Easting: 3095454.72

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	POCKET PENETROMETER (P, tsf)	DRY DENSITY (pcf)	UNDRAINED SHEAR STRENGTH (tsf)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	LL	PL	PI	PASSING #200 SIEVE (%)
0		6" Asphalt									
		6" Crushed gravel base					26				
		Fat Clay (CH), high plasticity, dark gray .. very stiff, light gray & tan below 2'	3.0				22	68	22	46	88
5			2.75				23				
		.. with calcareous nodules below 6'	2.5	102	0.95	0	22				
	CH	.. with ferrous nodules below 8'	3.0				24	69	22	47	90
10		.. with slickensided layer below 10'	2.75				24				
			3.5	101	1.1	0	25				
15			2.0				25	79	23	56	88
		Sandy Lean Clay (CL), stiff, high plasticity, light gray & tan	1.75				20				
			1.5	109	0.79	13	19				
20	CL	.. very stiff, with calcareous nodules below 20'	4.0				14	40	17	23	70
		.. stiff below 22'	2.0	122	0.75	0	14				

Other column headings: SAMPLES; WATER LEVEL; BLOW COUNT (N, Blows/Foot); FAILURE STRAIN (%); ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS; ATTERBERG LIMITS(%): LIQUID LIMIT, PLASTIC LIMIT, PLASTICITY INDEX.

Plot scales: ● N (blows/ft) ● 20 40 60 80; ▲ UU (tsf) ▲ 1.0 2.0 3.0 4.0; ★ DD (pcf) ★ 90 100 110 120; ◆ P (tsf) ◆ 1.0 2.0 3.0 4.0

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit; 20 40 60 80

Water Level Intial: ▽ After Drilling: ▼ 24 Hrs: ▼
Water Observations: Initial Water Level: Dry, After Drilling: Dry

Sample Key: ☒ SPT ▱ Shelby Tube ▤ Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
Q_u - Unconfined Comp. Strength (tsf)
DD - Dry Density (pcf)

Notes:
Augered dry to 24' & Hole Grouted after Drilling. Drilled By: Soltek, LLC, Logged BY: PV, Checked By: Jitu/pankaj, QC/QA By: PST

Associated Testing Laboratories, Inc.
3143 Yellowstone Blvd
Houston, Texas-77054

LOG OF BORING B-4 (PZ-2)

PROJECT: Proposed Southwest Pump Station Improvements-Package II
WBS No. S-001000-0047-3

PROJECT NO.: G13-225 BORING TYPE: Auger

DATE: 11-4-13

SURFACE ELEVATION: 58.23

LOCATION

Richmond Avenue
Northing: 13830965.8
Easting: 3095367.67

MATERIAL DESCRIPTION

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	POCKET PENETROMETER (P, tsf)	BLOW COUNT (N, Blows/Foot)	DRY DENSITY (pcf)	UNDRAINED SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0–6	CL	Lean Clay With Sand (CL), firm, high plasticity, light gray & tan	1.0						19	47	18	29	81	
			2.5		104	0.95		0	22					
		.. hard, with calcareous nodules below 4'	4.5						13					
6–14	CH	Fat Clay With Sand (CH), hard, high plasticity, light gray & tan	4.5						15	60	20	40	85	
		.. very stiff below 8'	3.25						27					
		.. with calcareous nodules below 10'	3.5						18					
			2.0		108	0.7		0	19					
14–28	CL	Sandy Lean Clay (CL), stiff, medium plasticity, light gray & tan	1.75						17	36	17	19		
		.. very stiff below 16'	3.25		111	1.19		12	19					
			3.5		113	1.0		0	18					
		.. with ferrous nodules below 23'	3.25						13	30	16	14	55	
28–34	SM	Silty Sand (SM), loose, non plastic, light gray & tan (wet)		10					22				15	
				12					21					

Graph legend: N (blows/ft) 20 40 60 80; UU (tsf) 1.0 2.0 3.0 4.0; DD (pcf) 90 100 110 120; P (tsf) 1.0 2.0 3.0 4.0

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit; 20 40 60 80

Water Level Intial: ▽ After Drilling: ▼ 24 Hrs: ▼

Water Observations: Initial Water Level: 28', After 5 minutes: 19', Borehole caved in at 27'

Sample Key: SPT Shelby Tube Disturbed

Key to Abbreviations:
- N - SPT Data (Blows/Ft)
- P - Pocket Penetrometer (tsf)
- T - Torvane (psf)
- Q_u - Unconfined Comp. Strength (tsf)
- DD - Dry Density (pcf)

Notes:
Augered dry to 34' ; PZ water level: 17' (11-5-2013); PZ water level: 12.5' (11-14-2013); PZ water level: 11' (12-6-2013); Drilled By: Soltek, LLC, Logged BY: PV, Checked By: Jitu/pankaj QC/QA By: PST

Associated Testing Laboratories, Inc.
3143 Yellowstone Blvd
Houston, Texas-77054

LOG OF BORING B-5

DATE 11-6-13

PROJECT: Proposed Southwest Pump Station Improvements-Package II
WBS No. S-001000-0047-3

SURFACE ELEVATION 56.88

PROJECT NO.: G13-225 BORING TYPE: Auger

LOCATION
Richmond Avenue
Northing: 13830956.89
Easting: 3094929.86

DEPTH (ft.)	USC	MATERIAL DESCRIPTION	POCKET PENETROMETER (P, tsf)	BLOW COUNT (N, Blows/Foot)	DRY DENSITY (pcf)	UNDRAINED SHEAR STRENGTH (tsf)	FAILURE STRAIN (%)	CONFINING PRESSURE (psi)	MOISTURE CONTENT (%)	LL	PL	PI	PASSING #200 SIEVE (%)	ESTIMATED ANGLE OF INTERNAL FRICTION (°), OTHER TESTS & REMARKS
0	CL	Fill: Lean Clay With Sand (CL), very stiff, high plasticity, light gray & tan	3.25						13					
	CH	Fat Clay With Sand (CH), very stiff, high plasticity, light gray & tan	3.5						19	61	21	40	78	
5		.. stiff below 4'	2.0		105	0.8		0	21					
		.. very stiff, with ferrous nodules below 6'	3.0						23					
		.. stiff below 8'	2.0						31					
10		.. firm, with vertical sand seams between 10' to 12'	1.0						26	54	19	35	80	
		.. stiff, with calcareous nodules below 12'	2.0						19					
15		.. very stiff below 14'	3.5		111	1.05		0	19					
	CL	Lean Clay With Sand (CL), very stiff, high plasticity, light gray & tan	3.25						18	48	18	30	76	
		.. with ferrous nodules below 18'	4.0		122	1.85		0	13					
20														
25		.. hard below 23'	4.5		118	2.05		0	15	40	17	23		
	SM	Silty Sand (SM), medium dense, non plastic, light gray & tan		12					21				30	

Plot headings: N (blows/ft) 20 40 60 80; UU (tsf) 1.0 2.0 3.0 4.0; DD (pcf) 90 100 110 120; P (tsf) 1.0 2.0 3.0 4.0

Natural Moisture Content and Atterberg Limits: Plastic Limit, Moisture Content, Liquid Limit; 20 40 60 80

Water Level Intial: ∇ After Drilling: ▼ 24 Hrs: ▼

Water Observations: Initial Water Level: 27', After Drilling: N/A.

Sample Key: SPT Shelby Tube Disturbed

Key to Abbreviations:
N - SPT Data (Blows/Ft)
P - Pocket Penetrometer (tsf)
T - Torvane (psf)
Q_u - Unconfined Comp. Strength (tsf)
DD - Dry Density (pcf)

Notes:
Augered dry to 29' & Hole Grouted after Drilling. Drilled By: Soltek, LLC, Logged BY: PV, Checked By: Jitu/pankaj, QC/QA By: PST

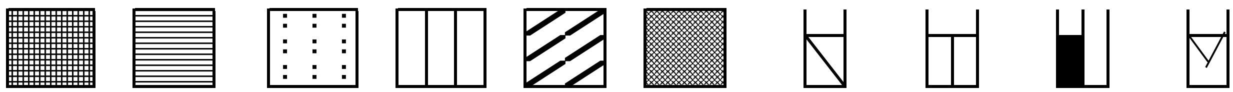
KEY TO LOG TERMS AND SYMBOLS

SOIL TYPE

SAMPLER TYPE

ROCK | GRAVEL | SAND | SILT | CLAY | PEAT | NO SAMPLE | AUGER SAMPLE | SHELBY TUBE | SPLIT SPOON

MODIFIER



STONE | GRAVELY | SANDY | SILTY | CLAYEY | FILL | NO RECOVERY | ROCK CORE | 2" SHELBY TUBE | TXDOT CONE

UNIFIED SOIL CLASSIFICATION SYSTEM - ASTM D 2487

MAJOR DIVISIONS			LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS LESS THAN 50% PASSING No. 200 SIEVE	GRAVEL & GRAVELY SOILS LESS THAN 50% PASSING No.4 SIEVE	CLEAN GRAVELS LITTLE OR NO FINES	GW	WELL GRADEED GRAVELS,GRAVELSAND MIXTURES WITH LITTLE OR NO FINES
			GP	POORLY GRADED GRAVELS,GRAVEL SAND MIXTURES WITH LITTLE OR NO FINES
		W/ APPRECIATEBLE FINES	GM	SILTY GRAVELS,GRAVEL SAND-SILT MIXTURES
			GC	CLAYEY GRAVELS,GRAVEL SAND-CLAY MIXTURES
	SANDS MORE THAN 50% PASSING No.4 SIEVE	CLEAN SANDS LITTLE FINES	SW	WELL GRADED SAND,GRAVELY SAND (LITTLE FINES)
			SP	POORLY GRADED SANDS,GRAVELY SAND(L. FINES)
		SANDS WITH APPREA. FINES	SM	SILTY SANDS,SAND-SILT MIXTURES
			SC	CLAYEY SANDS,SAND-CLAY MIXTURES
FINE GRAINED SOILS LESS THAN 50% PASSING NO. 200 SIEVE	SILTS AND CLAYS LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS & VERY FINE SANDS,ROCK FLOUR SILTY OR CLAYEY FINE SANDS OR CLAYEY SILT W/PI
			CL	INORGANIC CLAY OF LOW TO MEDIUM PI LEAN CLAY, GRAVELY CLAYS,SANDY CLAYS,SILTY CLAYS
			OL	ORGANIC SILTS & ORGANIC SILTY CLAYS OF LOW PI
	SILTS AND CLAYS LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS,MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS
			CH	INORGANIC CLAYS OF HIGH PLASTICITY FAT CLAYS
			OH	ORGANIC CLAYS OF MED TO HIGH PI, ORGANIC SILT
HIGHLY ORGANIC SOIL			FT	PEAT AND OTHER HIGHLY ORGANIC SOILS
UNCLASSIFIED FILL MATERIALS			ARTIFICIALLY DEPOSITED AND OTHER UNCLASSIFIED SOILS FILL MATERIALS	

CONSISTENCY OF COHESIVE SOILS

CONSISTENCY	UNCONFINED COMP. STRENGTH IN TSF
VERY SOFT	LESS THAN 0.25
SOFT	0.25 TO 0.5
FIRM	0.5 TO 1.0
STIFF	1.0 TO 2.0
VERY STIFF	2.0 TO 4.0
HARD	GREATER THAN 4.0

CONSISTENCY	UNCORR. POCKET PENTROMETER READ.
VERY SOFT	LESS THAN 0.25
SOFT	0.25 TO 0.5
FIRM	> 0.50 TO 1.50
STIFF	> 1.50 TO 3.00
VERY STIFF	> 3.0 TO 4.50
HARD	4.5+

RELATIVE DENSITY - GRANULAR SOILS

CONSISTENCY	N-VALUE (BLOWS PER FT)
VERY LOOSE	<4
LOOSE	5-10
MEDIUM DENSE	11-30
DENSE	31-50
VERY DENSE	>50 OR 50+

CLASSIFICATION OF GRANULAR SOILS

U.S.STANDARD SIEVE SIZE(S)

6" | 3" | 3/4" | 4 | 10 | 40 | 200

BOULDERS	COBBLES	GRAVEL		SAND			SILT OR CLAY	CLAY
		COARSE	FINE	COARSE	MEDIUM	FINE		

152 | 76.2 | 19.1 | 4.76 | 2.0 | 0.42 | 0.074 | 0.002

GRAIN SIZE IN MM

Associated Testing Laboratories, Inc